TECHNICAL MEMORANDUM NO. 3-331

FORECASTING TRAFFICABILITY OF SOILS

Report 10

RELATIONS OF STRENGTH TO OTHER PROPERTIES OF FINE-GRAINED SOILS AND SANDS WITH FINES

by

J. G. Collins

July 1971

Sponsored by U. S. Army Materiel Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

REPORTS OF THE SERIES ENTITLED "FORECASTING TRAFFICABILITY OF SOILS" TECHNICAL MEMORANDUM NO. 3-331

Report No.	Title	Date
1	Meteorological and Soil Data, Vicksburg, Miss., 1948-1949	Oct. 1951
2	Meteorological and Soil Data, Vicksburg, Miss., 1949-1951	June 1952
3	The Development of Methods for Predicting Soil-moisture Content	Oct. 1954
4	Information for Predicting Moisture in the Surface Foot of Various Soils	Feb. 1957
5	Development and Testing of Some Average Relations for Predicting Soil Moisture	May 1959
6	Airphoto Approach, Volumes 1 and 2	June 1963
7	A Pilot Study of Soils Subjected to Freezing and Thawing	June 1964
8	Variability of Physical Properties of Loess Soils, Warren County, Mississippi	Dec 1967
9	Water Table Study at Crossett, Arkansas	July 1968
10	Relations of Strength to Other Properties of Fine-Grained Soils and Sands with Fines	July 1971

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13. ABSTRACT

Attempts were made to establish relations between cone index, rating cone index, and remolding index (penetrometer strength measures commonly used in soil trafficability studies) and moisture content, soil separates contents, Atterberg limits, organic matter content, and dry density. Analyses were based on 6- to 12-in. soil layer data from 95 widely varying soils. In general, the approach followed in analyzing data was to (a) express the relation between a measure of strength and moisture content for each site with one standard equation form, (b) select coefficients that would define the strength-moisture relation for each site, and (c) relate the coefficients to soil properties. Results of the analyses indicate that usually (a) strength decreases with an increase in moisture for a given soil, (b) at a given strength level moisture content increases with a decrease in grain size or an increase in plasticity but is not associated with changes in organic matter content or dry density, (c) at a given moisture content changes in strength are associated primarily with changes in clay and/or sand contents when the U. S. Department of Agriculture soil separates are considered and with plastic and/or liquid limits when the Atterberg limits are considered, and (d) the predictive power of derived strength relations is poor even though the relations are significant (5% level). Appendixes are included in which the basic data and procedures used in obtaining the data are presented.

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FOREWORD

The study reported herein represents a partial fulfillment of the objectives of the Department of the Army Research and Development Project 1-T-0-62103-A-046, "Trafficability and Mobility Research," Task 02, "Surface Mobility," sponsored by the Research, Development and Engineering Directorate, U. S. Army Materiel Command. Parts of the analysis and report preparation were conducted under Project 1-T-0-62112-A-131, "Environmental Constraints on Materiel."

Acknowledgment is made to personnel of the Vicksburg Research Center (no longer in existence) of the Southern Forest Experiment Station, U. S. Forest Service, U. S. Department of Agriculture, who helped make arrangements for and participated in the collection of field data used in this study. Acknowledgment is also made to personnel of the agencies listed below who assisted in collecting and supplying data.

U. S. Forest Service Experiment Stations:

Intermountain
Lake States
Northeastern
Pacific Southwest
Rocky Mountain
Southeastern
Southern

U. S. Soil Conservation Service Stations:

Coshocton, Ohio
East Lansing, Michigan
State College, Mississippi

Educational Institutions:

Purdue University
South Dakota School of Mines and Technology
University of Illinois

University of Missouri
University of Nebraska
University of South Carolina

Field work was conducted during 1951-1957.

The study was completed by personnel of the Terrain Analysis Branch (TAB), Mobility and Environmental (M&E) Division, U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Messrs. W. G. Shockley, Chief, M&E Division; S. J. Knight, Assistant Chief, M&E Division; W. E. Grabau, Chief, TAB; E. S. Rush, Engineer, Vehicle Studies Branch, M&E Division; and M. P. Meyer, Engineer, TAB. The data were analyzed and the report was written by Mr. J. G. Collins.

Directors of the WES during the final preparation of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Director was Mr. Frederick R. Brown.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square inches	6.4516	square centimeters
square feet	0.092903	square meters
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
pounds per cubic foot	16.0185	kilograms per cubic meter

SUMMARY

The primary objective of this study was to derive relations between soil strength and other soil properties that can be used to predict soil trafficability.

Data from 95 test sites were used. Although all of the sites were located in the continental United States (and therefore within the temperate zone) they varied greatly with respect to soil, climate, and physiography.

The measures of soil strength analyzed were cone index (CI), rating cone index (RCI), and remolding index (RI). Soil properties analyzed with respect to strength included moisture content (MC); classes as defined by the U. S. Department of Agriculture (USDA) textural soil classification system and the Unified Soil Classification System (USCS); USDA sand, silt, and clay contents; USCS fines content; Atterberg liquid limit, plastic limit, and plasticity index; organic matter content; and dry density. Analyses were based only on data from the 6- to 12-in. soil layer.

Logarithmic equations (linear with logarithmic coordinates) were statistically derived for each set of CI-MC and RCI-MC data for a site with three or more observations. From those sites with significant (5% level) relations, data from 72 and 33 sites were selected for additional CI and RCI analyses, respectively. For the selected sites, values of MC at two levels of CI and RCI (called CI-MC and RCI-MC coefficients) were computed from the above-noted equations; relations between the coefficients and soil properties were then statistically derived. Results of these analyses indicated the following:

- a. CI and RCI decrease with an increase in MC.
- b. Arithmetic slopes of CI-MC relations are approximately parallel regardless of soil characteristics. Arithmetic slopes of RCI-MC relations tend to become flatter with decreases in grain size or increases in plasticity.
- c. CI and RCI are very sensitive to changes in MC.
- d. Significant relations exist between MC at given levels of CI and RCI and several soil properties.
- e. Values of MC at given levels of CI and RCI increase with a decrease in grain size or an increase in plasticity.

f. At a given MC, changes in CI and RCI are associated primarily with clay and/or sand contents when the USDA soil separates are considered and with plastic and/or liquid limits when the Atterberg limits are considered.

Two general methods of predicting CI and RCI were developed. The first method was based on the relations between soil properties and MC at given levels of CI and RCI; required inputs are soil properties and an MC. The second method was based on the relation between CI-MC coefficients and the relation between RCI-MC coefficients; required inputs are a representative CI-MC or RCI-MC observation. Predictions were made with data used in developing relations; accuracies were not good. Based on the Atterberg limits, for example, standard deviations of predicted CI ranged from about 27 at a CI level of 50 to about 133 at a CI level of 300; for RCI, standard deviations ranged from about 19 at an RCI level of 25 to about 94 at an RCI level of 200.

Logarithmic equations were also derived for each set of RI-MC data with three or more observations; too few (18) relations were significant to proceed with the same types of analyses used for CI and RCI. Relations were established, however, between mean RI ($\overline{RI}$) and soil properties; 52 sites with standard deviations from the mean of <0.08 RI unit were selected for this purpose. Results were as follows:

a. Significant relations exist between $\overline{RI}$ and several soil properties.

b. $\overline{RI}$ increases with a decrease in grain size or an increase in plasticity.

Because of the relation that exists between the three strength measures studied, i.e., RCI = (CI)(RI), RI-MC-soil property relations were studied using the previously derived CI and RCI relations. Results were as follows:

a. For most soils RI decreases with an increase in MC. The sensitivity of RI to changes in MC decreases with a decrease in grain size or an increase in plasticity, apparently to a point where RI is not associated with MC.

b. At a given MC, changes in RI are associated primarily with clay and/or sand contents when the USDA soil separates are considered and with plastic and/or liquid limits when the Atterberg limits are considered.

Two appendixes are included in which the basic data and procedures used in obtaining the basic data are presented.

FORECASTING TRAFFICABILITY OF SOILS

RELATIONS OF STRENGTH TO OTHER PROPERTIES OF FINE-GRAINED SOILS AND SANDS WITH FINES

PART I: INTRODUCTION

Background

1. The U. S. Army Engineer Waterways Experiment Station (WES) was introduced to the field of trafficability in 1945. At that time WES was requested by the Engineer Board (now the U. S. Army Mobility Equipment Research and Development Center) to assist in developing procedures for measuring soil trafficability in order that the off-road performance of military vehicles could be predicted. In response to this and subsequent requests, several test programs designed to establish soil-vehicle performance relations were conducted. Some of the results of tests on fine-grained soils and sands with fines, poorly drained are discussed in the following subparagraphs.

- a. A trafficable soil condition was defined as being one that permits 40-50 passes, with stopping if necessary, of a given vehicle operating at slow speeds in the same ruts. This condition also allows the vehicle to enter the area, stop, back out of the ruts while turning, and retreat from the area.
- b. The 6- to 12-in.* soil layer was considered to be the critical layer because the strength of this layer could be related to the 40- to 50-pass performance of most military vehicles.
- c. For prepared soils (reworked to uniform moisture and density conditions) consistent relations were found to exist between the cone index (a measure of soil strength) of the critical layer and vehicle performance.
- d. For natural soils it was found that soil strength almost always changes with traffic, and that the remolded strength (rating cone index, RCI) of the critical layer is closely related to vehicle performance.

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* A table of factors for converting British units of measurement to metric units is given on page ix.

e. For each vehicle tested a minimum RCI (vehicle cone index, VCI) was found to exist, below which the vehicle could not complete 40-50 passes. VCI is dependent upon and can be estimated from vehicle parameters, but it is independent of soil characteristics. A condensed tabulation of VCI's of standard military vehicles follows.

Vehicle Cone Index Range	Vehicle and Vehicle Types
20-29	M29C weasel, M76 otter, Canadian snowmobile, and some lightweight experimental vehicles. Example: VCI of M29C weasel = 25.
30-49	Engineer and high-speed tractors with comparatively wide tracks and low contact pressures. Examples: VCI of D7 engineer tractor = 40; VCI of M114 armored personnel carrier = 37.
50-59	Tractors with average contact pressures, tanks with comparatively low contact pressures, and some trailed vehicles with very low contact pressures. Example: VCI of M48 medium tank = 52.
60-69	Most medium tanks, tractors with high contact pressures, and all-wheel-drive trucks and trailed vehicles with low contact pressures. Example: VCI of M135, 2-1/2-ton truck = 62.
70-79	Most all-wheel-drive trucks, a great number of trailed vehicles, and heavy tanks. Example: VCI of 1-1/2-ton, 4x4 dump truck = 73.
80-99	A great number of all-wheel-drive and rear-wheel-drive trucks, and trailed vehicles intended primarily for highway use. Example: VCI of 1/2-ton, 4x2 pickup truck = 88.
100 or greater	Rear-wheel-drive vehicles and others that generally are not expected to operate off roads, especially in wet soils. Example: VCI of 5-ton, 4x2 dump truck = 119.

The procedures for measuring the trafficability of soils developed from the test programs satisfied the original request of the Engineer Board.

2. Recently, investigations have been made into variable pass performances of vehicles on fine-grained soils. Results are not yet conclusive. In accordance with the 40- to 50-pass criteria, however, indications are that the capability of a vehicle for completing a given number of passes on a given soil, provided that adequate traction capacity exists,

is dependent upon the cone index (CI) of a particular soil layer corrected for remolding effects. The results indicate that the depth at which the critical layer lies is a function of vehicle contact pressure. For most military vehicles results tend to confirm that the 6- to 12-in. layer is the critical layer, but that the critical layer lies at shallower depths for tracked vehicles and at deeper depths for very heavy, wheeled vehicles. Also, indications are that the amount of soil remolding beneath a vehicle increases with an increase in number of passes and that results from the standard remolding tests, which were designed to measure soil remolding on a 40- to 50-pass basis, are not directly applicable if only one pass or a few passes of a vehicle are made.

3. Earlier studies at the WES showed that for a given soil, strength changes are closely related to changes in moisture content. At the request of the Corps of Engineers, a study was initiated in 1951 by the Forest Service, U. S. Department of Agriculture (USDA), to develop methods for predicting moisture content of the 6- to 12-in. soil layer. Specifications were that the methodology be based on data readily available or on data easily obtainable in the field.

4. A program was initiated to collect data from a large number of sites diverse in soil, climate, and physiography in order that a widely applicable method for predicting moisture could be derived. Sites were established near Vicksburg, Miss.; teams were sent to Forest Service stations in various states to maintain site networks for at least one year; and arrangements were made with various universities and governmental agencies to collect data. A method for predicting soil moisture for fine-grained soil and sands with fines, poorly drained was developed and reported by the WES in 1959.[1a]

5. Soil strength data were also taken on a periodic basis at the above-noted sites. Coincident with and since the development of a moisture prediction system, studies have been made to establish relations between soil strength and other soil properties. These relations can be used in conjunction with the moisture prediction system to predict and possibly forecast soil trafficability.

Purpose

6. The purpose of this report is to present relations between soil strength and other soil properties, to explain how these relations were derived, and to show how they can be used in the prediction of soil trafficability.

Scope

7. Data collected during 1951-1957 from 95 test sites were used in this study. The sites were located in 20 states in the continental United States; general locations are shown in fig. 1. Although all sites were situated within the temperate zone they varied greatly with respect to soil, climate, and physiography. Data were collected only for fine-grained soils and sands with fines.

8. The measures of soil strength analyzed in this study were cone index (CI), remolding index (RI), and rating cone index (RCI). (The strength of soil, in situ, was measured with a cone penetrometer having a 30-deg right circular cone with a basal area of 0.5 sq in. mounted on a 5/8-in.-diam staff; the penetrometer provided maximum readings of 300 CI.) Soil properties analyzed with respect to strength included moisture content; classes as defined by the USDA textural soil classification system and Unified Soil Classification System (USCS); USDA sand, silt, and clay contents; USCS fines content; Atterberg liquid limit (LL), plastic limit (PL), and plasticity index (PI); organic matter content; and dry density. Analyses were based only on data from the 6- to 12-in. soil layer; therefore, results apply directly only to that layer.

9. Single- and multiple-factor relations were established between the soil strength measures and soil properties. Procedures for using derived relations for the prediction of CI and RCI were developed and evaluated.

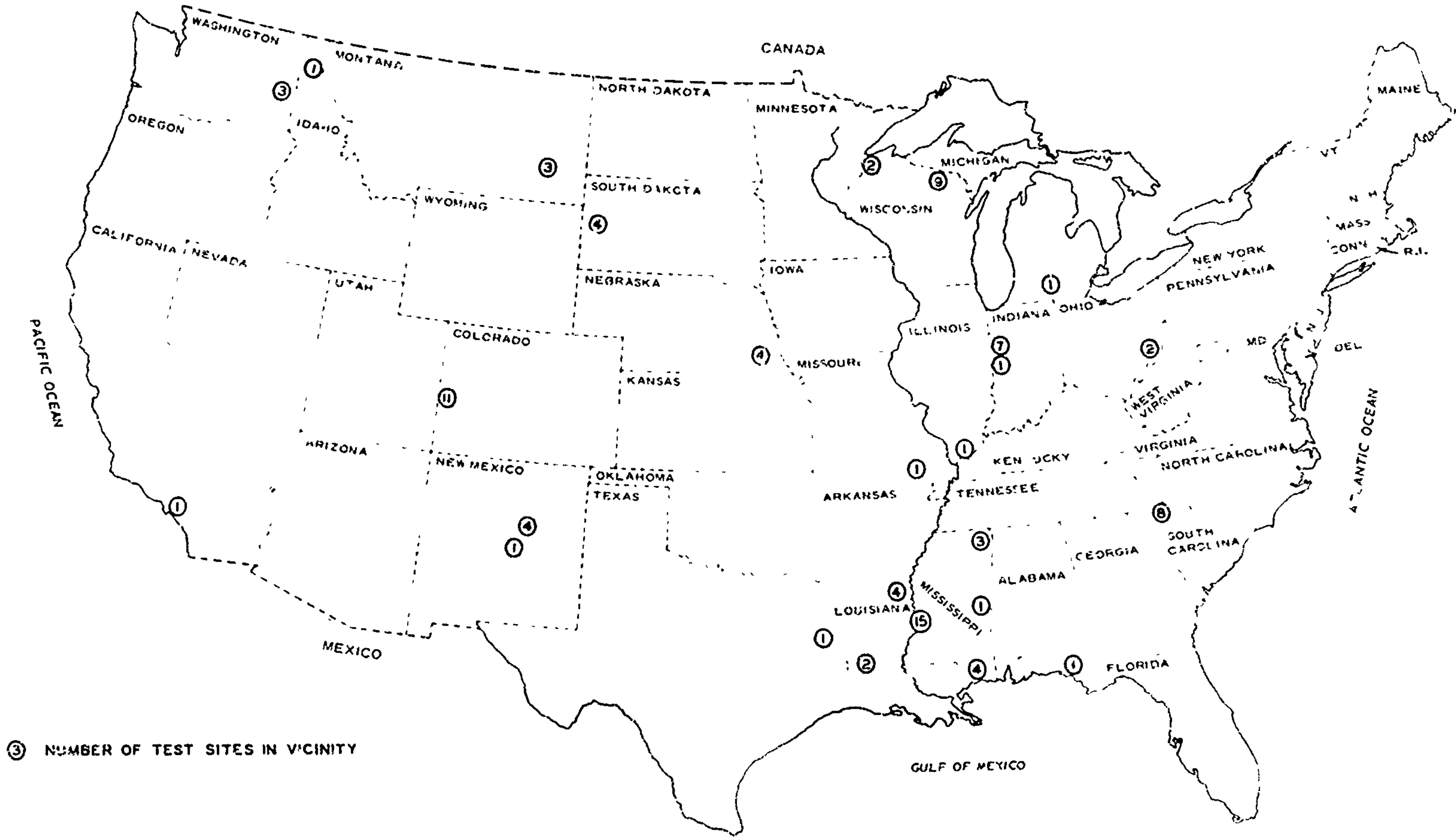

Fig. 1. Locations of test sites

PART II: ANALYSIS OF DATA

10. Analyses pertaining to CI, RCI, and RI are discussed separately herein. Some RI relations were established indirectly, i.e., on the basis of previously derived CI and RCI relations. For this reason, analyses pertaining to RI are presented last in this section.

11. Data on strength, moisture content (MC), and other physical properties of the soil are presented in Appendix A. Site descriptive data, although not used in the analysis, are also included for information purposes. The equipment used and procedures followed in measuring soil strength are presented in Appendix B.

Cone Index (CI)

12. Previous studies both in the laboratory and in the field have shown that for a given soil, an increase in MC is associated with a decrease in CI. Laboratory studies[2-4] have indicated that a relatively smooth, practically scatter-free curve of MC versus CI exists for a given soil (and given compactive effort), and moreover that the curve shape (but not its position on the axes) is generally similar for a wide variety of fine-grained soils. Although it was known that field data seldom produced smooth, scatter-free curves[1b,2,3,5-7] the laboratory results suggested that it would be worthwhile to pursue the following approach for establishing CI-soil property relations: (a) express the relation between CI and soil MC for each site with one standard equation form, (b) select coefficients that would define the CI-MC relation for each site, and (c) relate the coefficients to individual soil properties and combinations of soil properties. The ensuing analyses are discussed in the following paragraphs.

CI-MC relations

13. CI values that were used in the CI-MC analysis were averaged for a given visit to a site. These site-visit averages are referred to as CI values or measurements in this report. It was recognized that some of these values were not true site averages because 300+ readings were included (see paragraph 6 of Appendix B). No attempt was made to eliminate

all site average values that included 300+ readings. However, to eliminate some of the erroneous data, site average values of 300+ were excluded in all CI-MC relation derivations.

14. A brief résumé of data that remained for analysis is tabulated below.

No. of CI-MC Observations	No. of Sites	No. of CI-MC Observations	No. of Sites
0-2	0	30-39	5
3-9	14	40-49	9
10-19	48	50-59	4
20-29	12	60+	3
		Total	95

A sufficient number of observations (i.e. three or more) were made at all sites to statistically derive and evaluate CI-MC relations.

15. Selection of equation form. The general trend of decreasing CI with increasing MC has been found in both field and laboratory studies. The trend of plotted field data for a site with maximum CI values of 300 can seldom be positively distinguished as being something other than linear (see plate 1). However, plotted results of laboratory tests with processed soils[2,3] and field tests with CI values ranging to 750[5,7] usually form distinct curves that are approximately logarithmic in form, i.e.

$$\ln CI = a + b(\ln MC)$$

16. An attempt was made to determine whether the linear or logarithmic equation form was more appropriate for expressing the relation between field-measured CI and MC. Correlation coefficients were computed using both arithmetic and logarithmic values of CI and MC for each of the 95 sets of data. When carried to three decimal places the correlation coefficients based on logarithmic values were higher for 43 sets of data and lower for 51 sets (values were equal for one set of data). Although slightly favoring a linear relation, the difference in the above-mentioned numbers was nonsignificant and could easily be attributed to chance. Furthermore,

correlation coefficients were nearly the same in all cases, the largest difference in correlation coefficients favoring the linear relation for a given set of data being only 0.085.

17. It was also recognized that three factors would tend to mask a curvilinear relation: (a) the scatter of data, (b) the short ranges over which CI and MC were generally measured, and (c) the inclusion of site average CI's that were based on one or more 300+ readings (these would tend to be lower than the true CI values and be clustered at low moisture contents).

18. It was finally decided to relate CI and MC on a logarithmic basis primarily because of the following reasons.

- a. The relations for data obtained in laboratory studies and in field tests with CI values ranging to 750 were approximately logarithmic in form.
- b. The use of a logarithmic equation eliminated the possibility of extrapolating into negative CI and MC ranges.

19. Derivation of relations. An attempt was first made to derive CI-MC relations using conventional regression analysis techniques. Results, however, indicated that high CI (the dependent variable) values were being estimated low and low CI values were being estimated high, a common phenomenon associated with the regression analysis.

20. It was particularly desirable to estimate low CI values more accurately since they are indicative of critical soil trafficability conditions. Hence, CI-MC relations were rederived using reduced major axis analysis techniques.[8-10] Results showed that these relations (hereafter referred to as specific relations) more closely approximated low measured CI values than did the relations derived by conventional regression analysis techniques.

21. Numbers of observations, correlation coefficients, levels of significance (1% and 5%), and equations of specific relations significant at the 5% level are included in table 1. For the 95 sites, 72 (76%) of the relations were significant at the 5% level, and 64 (67%) were significant at the 1% level. All relations significant at the 5% level showed that CI decreases with an increase in MC. Measurement deviations are discussed in paragraph 110 of Part III.

22. Selection of sites for further analysis. Before conducting analyses relating equations or expressions of equations to soil properties it was considered necessary to select sites with reliable CI-MC relations. For this purpose, the level of significance was considered to be the most meaningful criterion that could be used. All relations not significant at the 5% level (an arbitrary but often used limit) were rejected from further consideration. Although an acceptable minimum CI range was not set, the range of data for each site was also checked. All of the 72 sites having significant relations were accepted; none were rejected because of what was considered to be an inadequate range of CI.

CI-MC coefficients

23. The derived CI-MC relations plotted as straight lines on logarithmic graph paper. A straight line may be completely defined by the coordinates of two points on the line, or by the coordinates of one point on the line and the slope of the line. Likewise, an accurate estimate of any two of the above-noted quantities provides an accurate estimate of the line.

24. Selection of CI-MC coefficients. An attempt was first made to relate slope and intercept values (b and a values, respectively, as shown in table 1) to soil properties. Significant multiple-factor relations were found with several groups of soil properties, but subsequent CI predictions based on these relations were not good. Two possible explanations for the poor results are as follows:

a. The intercept is the log of CI at 1% MC. For each site the derived value represented a point below the natural range of soil MC and generally far above the measurable range of CI (i.e., far above 300 for the 0.5-sq-in. cone penetrometer; see Appendix B).

b. These coefficients were found to be very sensitive in terms of CI. For example, an apparently minor error in slope estimation for a line originating at the derived intercept often resulted in large deviations throughout the range of measured data.

25. As indicated in paragraph 23, values of CI at two given levels of MC or values of MC at two given levels of CI could be used to define a CI-MC relation. A cursory examination of the data indicated, however, that

no one level of soil moisture content occurred naturally at all sites. At any level, gross extrapolations had to be made for many sites. Graphs of CI at a given moisture level versus each of several soil properties were compiled, but these graphs did not show any relations. The use of CI at given moisture levels was not considered further.

26. The use of soil MC's at given levels of CI appeared more promising. The ranges of CI measurements for practically all sites were found to overlap considerably; this meant that CI levels could be selected that were within the natural strength range of almost all sites. Furthermore, plotted CI-MC relations generally shifted to higher MC's as soil moisture-holding capacity increased. For example, the highest measured MC's for the four sites shown in plate 1 are approximately 19%, 26%, 36%, and 48%; MC's at the 150-CI level increase in the same order, i.e., approximately 15%, 26%, 32%, and 39%. Many studies have been made relating soil moisture-holding characteristics to soil properties;[11,12] this suggested that the position of the CI-MC relations with respect to the MC ordinate should also be related to soil properties.

27. MC's at 200 CI and 300 CI were selected as CI-MC coefficients for use in further analyses; these values, computed from specific CI-MC relations, are shown in table 1. As noted in paragraph 13, 300+ CI values were not included in the derivation of CI-MC relations; however, most sites had measurements close to 300. It would have been desirable to use MC's at a CI level lower than 200, i.e., in a range more critical with respect to trafficability; this was not done because the data would have had to be extrapolated for many sites.

28. <u>Sensitivity of CI-MC coefficients.</u> The CI-MC coefficients selected were in units of percent MC. As it was desirable to evaluate the accuracy of CI-MC coefficient estimations in terms of CI, average effects of MC on CI were determined.

29. The average changes in MC were computed for eight changes in CI (plus and minus 10, 20, 30, and 40 units) at four levels of CI (100, 150, 200, and 250), and for four changes in CI (minus 10, 20, 30, and 40 units) at the 300-CI level. Computations were made using the 72 specific relations noted in paragraph 22. No gross extrapolations were made; hence,

average changes of MC were not made for positive changes in CI at the 300-CI level. Also the number of specific relations used decreased as CI decreased; computations were based on only seven of the specific relations at 70 CI (100-CI level with a -30 CI change).

30. Results of the analysis are shown graphically in plate 2. The average MC change for a given CI change increases as the CI level decreases. To achieve an average CI accuracy of ±20 units, the graph indicates that MC must be determined with an average accuracy of approximately 1.2%, i.e. $\frac{1.3 + 1.1}{2}$, at the 200-CI level. Likewise, if the standard deviation of estimated MC at 200 CI is 2.0% then the standard deviation of estimated CI at the 200-CI level should be approximately 35, i.e. $\frac{31 + 39}{2}$.

CI-MC coefficient-
soil property relations

31. Logarithmic values of the CI-MC coefficients were used in deriving relations. The transformation from arithmetic to logarithmic values was primarily made for two reasons.

- a. It simplified the approach whereby equations for estimating the CI-MC coefficients could be combined and reduced for the prediction of CI.
- b. It eliminated the possibility of estimating negative values of CI-MC coefficients.

32. Three ways of relating CI-MC coefficients to soil differences were explored: (a) by soil classes, separated on the basis of soil property criteria, (b) by individual soil properties, and (c) by grouped soil properties.

33. Soil classes. The effectiveness of soil classes for estimating CI-MC coefficients was determined for the USDA soil textural classification system and the USCS. Logarithmic values of each of the CI-MC coefficients were compiled by classes and the mean values computed. Pooled standard deviations (s_p) for the systems were then determined assuming that class variances were equal. Classes represented by only one site (zero degree of freedom) could not be included in s_p determinations.

34. Average values of the CI-MC coefficients by USDA textural classes are shown below. Classes are arranged in an increasing order of grain size. The CL, SCL, LS, SC, and Si classes were not represented or

were represented by only one site and, therefore, are not shown.

USDA Soil Class	No. Sites	Mean ln MC at 200 CI	Mean ln MC at 300 CI
C	6	3.352	3.198
SiC	2	3.451	3.290
SiCL	8	3.160	2.941
SiL	37	3.162	2.956
L	10	2.922	2.567
SL	4	2.338	1.980
S	2	2.173	1.330
All classes	69	3.075	2.825

Relatively few sites were included in most of the classes. Nevertheless, the data indicate that values of the CI-MC coefficients tend to decrease with increasing grain size. Pooled standard deviations from class means of ln MC at 200 CI and ln MC at 300 CI were 0.205 and 0.265, respectively; comparable arithmetic values at the mean logarithmic values of the CI-MC coefficients are both 4.5% MC. As indicated by the graph in plate 2, these deviations are large in terms of CI.

35. Average values of the CI-MC coefficients by USCS classes are shown below. Classes are arranged in a decreasing order of plasticity. The SC-SM, SC, MH, OL, and OH classes were not represented or were represented by only one site and, therefore, are not shown.

USCS Soil Class	No. Sites	Mean ln MC at 200 CI	Mean ln MC at 300 CI
CH	13	3.306	3.118
CL	30	3.074	2.880
ML	18	3.076	2.765
CL-ML	6	3.101	2.831
SM	4	2.275	1.560
All classes	71	3.074	2.816

The data indicate a tendency for values of the CI-MC coefficients to decrease with decreasing plasticity. There is no indication, however, that

criteria used to differentiate the CL, ML, and CL-ML classes are meaningful with respect to the coefficients. Pooled standard deviations from class means of ln MC at 200 CI and ln MC at 300 CI were 0.259 and 0.337, respectively; comparable arithmetic values were 5.7% MC and 5.6% MC, respectively. These deviations are larger than those of the USDA system and are large in terms of CI (plate 2).

36. Individual soil properties. Commonly measured soil properties were studied to determine if they were related to the CI-MC coefficients. Properties considered were USDA sand, silt, and clay contents; USCS fines content; Atterberg liquid limit, plastic limit, and plasticity index; organic matter content; and dry density. Regression analysis techniques were used to establish relations. To improve relations, ln or ln-ln values of some properties were used. Significant relations (5% level) and corresponding correlation coefficients and standard deviations from the regression are tabulated below; basic data and regression lines significant the 5% level are shown graphically in plates 3-7. Differences in the number of observations were due to the fact that measurements of some properties were not or could not be made for some sites (see table A2).

[illegible]

Soil Property (%)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sand		[illegible]	[illegible]2	-[illegible]**	[illegible]	[illegible]	[illegible]	-[illegible]**	[illegible]	[illegible]	[illegible]
Silt	[illegible]	[illegible]	72	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]
Clay	[illegible]	[illegible]	[illegible]2	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]
Fines		[illegible]	[illegible]2	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]2	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	44	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]
Organic matter	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	[illegible]	--	--	--
Dry density	[illegible]	[illegible]	[illegible]2	[illegible]	--	--	--	[illegible]	--	--	--

** Significant at [illegible] level.

37. Relations of the CI-MC coefficients with organic matter content and dry density were not significant at the 5% level. The limited range of organic matter content values (0.2-5.5%) may have been a major contributing factor in the nonsignificance of relations with this property. Dry density values were distributed over a somewhat normal range. Thus, the results

indicated that little of the variation in the CI-MC coefficients was associated with this soil property. This may be partially due to the fact that MC was expressed in terms of percent dry weight of soil; therefore, at a given MC the same amount of lubricant (water) existed per unit mass of soil regardless of dry density.

38. Seven of the nine pairs of relations were significant at the 1% level; six had positive regression coefficients (slopes), and one, the pair of relations with sand content, had negative coefficients. The signs of the regression coefficients indicate that at a given CI level, increases of MC are associated with increases in plasticity and decreases in grain size. As shown in plate 3, for example, at the 200-CI level the average MC's are approximately 9% and 26% for soils with sand contents of 90% and 10%, respectively. Conversely, the results indicated that at a given MC, increases of CI are associated with increases in plasticity and decreases in grain size. For example, at an MC of 20%, CI increases from 200 to 300 as sand content decreases from 30% to 13% (plate 3), and clay content increases from 13% to 28% (plate 4).

39. Results for some soil properties indicated that, arithmetically, the slopes of the CI-MC relations between the 200- and 300-CI levels are independent of differences in the soil property. This is demonstrated by the fact that relations of the CI-MC coefficients with sand content, as shown in plate 3, are approximately parallel. The relations between MC at 200 CI and MC at 300 CI were derived using reduced major axis analysis techniques; results of the analysis are shown graphically in plate 8. The slope of the relation was close to one on one, thus indicating that arithmetic slopes of CI-MC relations between the 200- and 300-CI levels tend to be consistent regardless of the soil moisture regimes within which these CI levels exist.

40. Relations between the CI-MC coefficients and silt content were statistically significant; there is, nevertheless, some question as to their validity. Plots of relations clearly show that the values of the CI-MC coefficients tend to increase with a decrease in sand content (plate 3) or an increase in clay content (plate 4). It was expected, therefore, that as silt content decreased the sand and/or clay content

would increase and values of the CI-MC coefficients would become more widely scattered. In general this was the case; however, of the four sites (sites 85, 90, 91, and 94) that had silt contents less than 20%, all had low clay contents (11%, 2%, 1%, and 1%, respectively) and, as could be expected, all had low CI-MC coefficient values. Assuming a more or less equal probability of low-silt-content soils having either high sand contents or high clay contents, it follows that the inclusion of these four sites was by chance and that the CI-MC coefficient-silt content relations are spurious. A related discussion is given in paragraph 70.

41. Considering both CI-MC coefficients, relations with sand content were better than with any other individual property tested. Standard deviations from the regression for ln MC at 200 CI and ln MC at 300 CI were 0.211 and 0.248, respectively. Estimations of the CI-MC coefficients using relations with sand content and using mean values of CI-MC coefficients for soil classes of the USDA textural soil classification system (paragraph 34) were about the same. Estimations of the CI-MC coefficients were better using relations with fines content, liquid limit, plastic limit, or plasticity index than by using means of CI-MC coefficients for USCS soil classes (paragraph 35) even though these soil properties are used in differentiating USCS classes.

42. Grouped soil properties. Using the WES electronic computer,[x] multiple regression analyses were made to establish relations between the CI-MC coefficients and groups of soil properties. The same soil properties and transformations considered in the individual soil property analysis (see paragraph 36) were tested.

43. The various combinations of soil properties tested are set forth briefly in the following subparagraphs.

a. All of the nine soil properties were made available for addition to the fit (inclusion in the equation).

b. USDA sand, silt, and clay contents were force fitted.

c. USDA sand, silt, and clay contents were force fitted;

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[x] General Electric-225 electronic computer. The program used is entitled "GE-200 Series Multiple Linear Regression Program II"; the program number is CD225D3.001.

organic matter content and dry density were made available for addition to the fit.

d. USCS fines content, liquid limit, plastic limit, and plasticity index were force fitted.

e. USCS fines content, liquid limit, plastic limit, and plasticity index were force fitted; organic matter content and dry density were made available for addition to the fit.

f. Liquid limit, plastic limit, and plasticity index were force fitted.

g. Liquid limit, plastic limit, and plasticity index were force fitted; organic matter content and dry density were made available for addition to the fit.

Available soil properties were added to the fit in the order in which they contributed in reducing the residual sum of squares (i.e., in reducing the previously remaining unexplained error). For an available property to be accepted in the fit, however, it had to make a significant (5% level) contribution in reducing error in MC at 200 CI. If a property was added to an equation for estimating MC at 200 CI it was automatically force fitted into the equation for estimating MC at 300 CI. Results of the multiple regression analyses are summarized in the following tabulation.

44. The partial regression coefficient expressed the magnitude and direction of change of the estimated dependent variable with a unit change in the independent variable. Relations derived by regression analyses are not necessarily "cause and effect" in nature. Consequently, the apparent effect of a given independent variable often changes markedly if grouped with different combinations of other independent variables; this phenomenon

is clearly demonstrated in the tabulation on the previous page by liquid limit. However, partial regression coefficients of both plastic limit and organic matter content were consistent in terms of sign and magnitude regardless of the grouping. These consistencies may indicate a natural association between these properties and the CI-MC coefficients.

45. The tabulation on the preceding page shows that the best three pairs of relations, as indicated by the standard deviations from regression, include properties associated with both grain size and plasticity; the poorest three relations included in the tabulation lacked one or the other types of these soil descriptors. This suggests that if reliable estimates of the CI-MC coefficients and therefore CI are to be made, both grain size and plasticity, or indicators thereof, may have to be considered.

46. Shown below is a résumé of accuracies of the CI-MC coefficient estimations for the two soil classification systems and for some of the soil properties, individually and in groups. Included are standard deviations of ln MC at 200 CI and ln MC at 300 CI and comparable arithmetic values, in percent MC.

	Standard Deviation			
	MC at 200 CI		MC at 300 CI	
Classification System or Soil Property(ies)	ln	Arithmetic Equivalent	ln	Arithmetic Equivalent
USDA System	0.205	4.5	0.265	4.5
USCS	0.259	5.7	0.337	5.6
Sand	0.211	4.6	0.248	4.2
Sand, PL, and organic matter	0.153	3.5	0.201	3.7
Sand, silt, and clay	0.209	4.5	0.245	4.1
Fines, LL, PL, and PI	0.161	3.7	0.219	4.0

47. On the basis of standard deviations the best estimates of the CI-MC coefficients were obtained with the pair of multiple-factor relations that included sand content, plastic limit, and organic matter. Standard deviations associated with relations incorporating the soil properties used in the USDA soil textural classification system (i.e. sand, silt, and clay) were approximately the same as those for the system itself. This indicates

that the use of redefined soil textural classes would not greatly improve the accuracies of CI-MC coefficient estimations and, therefore, CI. Standard deviations associated with the properties used in differentiating USCS classes (i.e. fines, LL, PL, and PI) are appreciably smaller than those for the system itself. This indicates that a better classification system for estimating the CI-MC coefficients could be devised based on the same defining soil properties.

CI-soil property relations

48. CI-soil property relations can easily be computed from the CI-MC coefficient relations previously described. For the general case, the equation defining a straight line is as follows:

$$Y = a + bX$$

Slope (b) and intercept (a) values can be determined in the following manner:

$$b = \frac{Y_1 - Y_2}{X_1 - X_2}$$

$$a = Y_1 - bX_1 = Y_1 - \left(\frac{Y_1 - Y_2}{X_1 - X_2}\right) X_1$$

By substituting these expressions of slope and intercept, the general case equation can be rewritten:

$$Y = Y_1 - \left(\frac{Y_1 - Y_2}{X_1 - X_2}\right) X_1 + \left(\frac{Y_1 - Y_2}{X_1 - X_2}\right) X$$

This equation can then be reduced to the following form:

$$Y = Y_1 - \left(\frac{Y_1 - Y_2}{X_1 - X_2}\right)(X_1 - X) = Y_1 - \frac{(Y_1 - Y_2)(X_1 - X)}{X_1 - X_2}$$

To put the equation above into the logarithmic form (see paragraph 15) and terms of CI, MC, and CI-MC coefficients, the following substitutions are made:

$Y = \ln CI$

$Y_1 = \ln 200\ CI = 5.29832$

$Y_2 = \ln 300\ CI = 5.70378$

$X = \ln MC$

$X_1 = \ln MC \text{ at } 200\ CI$

$X_2 = \ln MC \text{ at } 300\ CI$

Therefore

$$\ln CI = 5.298 + \frac{0.405\ (\ln MC \text{ at } 200\ CI - \ln MC)}{\ln MC \text{ at } 200\ CI - \ln MC \text{ at } 300\ CI}$$

Furthermore, by substituting CI-MC coefficient-soil property relations (paragraphs 34-36 and 43), CI can be expressed solely in terms of soil properties and MC.

49. An analysis was made of changes in CI associated with changes in values of some of the soil properties. At three levels of MC (20%, 30%, and 40%), CI values were computed for different combinations of values of soil properties included in each of two groups: (a) USDA sand, silt, and clay contents and (b) Atterberg liquid limit, plastic limit, and plasticity index. Values were selected within the approximate ranges of measured data included in this study. Computed CI values were plotted on textural triangles and plasticity charts. Isolines of CI were then drawn; these are shown in plates 9 and 10.

50. The data in plate 9 indicate that there are strong interacting effects on CI between MC and sand, silt, and clay contents. At the 20% MC level, CI changes are associated almost entirely with changes in sand content from 0 to about 60% (indicated by the fact that isolines of the two variables without this range are about parallel), CI increasing with a decrease in sand content. At the 40% MC level, CI changes appear to be associated almost entirely with changes in clay content, CI increasing with either an increase or decrease in clay content from approximately the 30% clay content level. At the 30% MC level, CI changes appear to be

associated with changes in both sand and clay contents. Silt content apparently has little effect on CI, at least for the MC levels tested.

51. The data in plate 9 also indicate that the weakest soils always have significant amounts of all three soil separates and that the amount of each soil separate varies with MC. Sand, silt, and clay contents corresponding to the lowest CI at each MC level studied are summarized below.

MC, %	Lowest CI	% Contents of Sand	Silt	Clay
20	132	77	17	6
30	94	56	29	15
40	64	23	47	30

The graphs show that for any given combination of sand, silt, and clay contents, CI decreases with an increase in MC.

52. Data shown in plate 10 indicate that there are also interacting effects on CI between MC and the Atterberg limits. At the 40% MC level, CI changes are associated almost entirely with changes in plastic limit, CI increasing with an increase in plastic limit. At the 20% MC level, CI changes are associated primarily with changes in plastic limit and secondarily with changes in liquid limit, CI increasing with an increase in both limits. For any given combination of the Atterberg limits tested, CI decreases with an increase in MC.

Rating Cone Index (RCI)

53. As in the case of CI, previous investigations have shown that for a given soil changes in RCI are associated with changes in MC, RCI increasing as MC decreases, but that for unlike soils RCI-MC relations are generally not the same.[1b,2,3,5-7] The same types of analyses used in establishing CI relations were used to establish RCI relations. Analytical procedures for CI were explained previously in detail; thus only abbreviated explanations of the procedures used in analyzing RCI are contained in this part of the report.

RCI-MC relations

54. As noted in paragraph 13, all 300+ CI values were excluded in the derivation of relations because they were known to be quantitatively erroneous in practically all cases. Since RCI is the product of CI and RI, it follows that RCI values corresponding to 300+ CI values are, in practically all cases, larger than indicated. They were, therefore, excluded in all derivations of RCI-MC relations.

55. A summary of data that remained for analysis is tabulated below:

No. of RCI-MC Observations	No. of Sites	No. of RCI-MC Observations	No. of Sites
0-2	27	20-29	4
3-9	38	30-39	2
10-19	22	40+	2

At many sites RI tests could not be made at times of low moisture contents, thus precluding the determination of RCI. As a result, the number of RCI observations per site was generally less than the number of CI observations. Of the 95 sites, 68 had a sufficient number of observations (more than 2) to statistically derive RCI-MC relations; of these, 56% (38 sites) had fewer than 10 observations.

56. Selection of equation form. The logarithmic equation was selected for use in relating RCI and MC, i.e.

$$\ln RCI = a + b(\ln MC)$$

This was done primarily because the trend between CI and MC in laboratory studies was known to be approximately logarithmic in form.[2,3] Although the remolding test (Appendix B) does not completely duplicate the laboratory processing of soils, which includes the removal of roots and stones and thorough mixing, the two processes are similar in that both involve the breaking down of natural soil structural units.

57. Derivation of relations. Based on the experience gained in working with CI (paragraphs 19 and 20), RCI-MC relations were derived using reduced major axis analysis techniques. Numbers of observations,

correlation coefficients, levels of significance (1% and 5%), and equations for relations significant at the 5% level are shown in table 2. For the 68 sites with three or more observations, 37 (54%) of the relations were significant at the 5% level, and 21 (31%) were significant at the 1% level. For all relations significant at the 5% level, RCI decreased with an increase in MC. Measurement deviations are discussed in paragraph 125 of Part III.

58. Selection of sites for further analysis. Relations between RCI and MC to be used in further analyses were selected on the basis of the level of significance, number of observations, and range of RCI values. Relations not significant at the 5% level, based on less than five observations, or based on a narrow range of RCI values were rejected. Using these criteria the relations for 33 sites were selected for further use.

RCI-MC coefficients

59. Selection of RCI-MC coefficients. MC's at given levels of RCI were considered for use as RCI-MC coefficients. As in the case of CI, the range of RCI measurements for practically all sites overlapped. Also, plotted RCI-MC relations, in general, shifted to higher MC's as the moisture-holding capacity of the soil increased. As shown in plate 11, the highest measured MC's are approximately 19%, 27%, 36%, and 48% for the four sites shown; MC's at the 100-RCI level increase in the same order, i.e. approximately 19%, 25%, 32%, and 46%.

60. MC's at the 100 and 200 levels of RCI (MC at 100 RCI and MC at 200 RCI) were selected as RCI-MC coefficients because an appreciable amount of measured data between these levels was available. Values of the coefficients, shown in table 2, were computed from specific RCI-MC relations.

61. Sensitivity of RCI-MC coefficients. Average effects of moisture content on RCI were determined using the 33 specific relations noted in paragraph 58. Average changes in MC were computed for eight changes in RCI (plus and minus 10, 20, 30, and 40 units) at four levels of RCI (100, 150, 200, and 250), and for four changes in RCI (minus 10, 20, 30, and 40 units). The number of specific relations decreased as RCI decreased; computations were based on only 20 of the specific relations at 60 RCI (100-RCI level with a -40 RCI change). Results are shown graphically in plate 12.

62. The data in plate 12 indicate that the average MC change for a given RCI change increases as the RCI level decreases. For an average RCI accuracy of ±20 units, MC at the 200- and 100-RCI levels must be determined with an average accuracy of approximately 0.6%, i.e. $\frac{0.6 + 0.6}{2}$, and 1.4%, respectively. If the standard deviation of estimated MC at 100 RCI is 2.0% then the standard deviation of estimated RCI at the 100-RCI level should be approximately 29, i.e. $\frac{25 + 33}{2}$. Results also indicate that RCI is more sensitive to changes in MC than is CI (see plate 2), i.e., at any given strength level the average change in RCI is greater than that in CI for a unit change in MC.

RCI-MC coefficient-
soil property relations

63. Logarithmic values of the RCI-MC coefficients were used in deriving relations; the reasons for the transformations from arithmetic values were the same as those for the CI-MC coefficients (paragraph 31). As in the case of CI, three ways of relating RCI-MC coefficients to soil differences were explored: (a) by soil classes, (b) by individual soil properties, and (c) by groups of soil properties.

64. Soil classes. The effectiveness of soil classes for estimating RCI-MC coefficients was determined on the basis of the pooled standard deviation for the USDA textural classification system and for the USCS. Average values of the RCI-MC coefficients for USDA textural classes are shown in the following tabulation. The SiC, CL, Si, SCL, SC, SL, LS, and S classes were not represented or were represented by only one site, and, therefore, are not included.

USDA Soil Class	No. Sites	Mean ln MC at 100 RCI	Mean ln MC at 200 RCI
C	3	3.726	3.503
SiCL	2	3.978	3.045
SiL	25	3.258	3.103
L	2	3.224	2.984
All classes	32	3.308	3.130

The tabulation shows that insufficient data were available to evaluate the system; mean values for only four classes were included and of these all except SiL were based on few observations (two or three). No sandy soils were included, but this was to be expected; in general, it is difficult to perform remolding tests, i.e. to obtain RCI, on these soils. For the data used, pooled standard deviations from class means of ln MC at 100 RCI and ln MC at 200 RCI were 0.159 and 0.190, respectively; comparable arithmetic values at the mean logarithmic values of the RCI-MC coefficients are both 4.4%. As indicated by the graph in plate 12, the deviations are extremely large in terms of RCI.

65. Average values of the RCI-MC coefficients by USCS classes are shown below, classes being arranged in order of decreasing plasticity.

USCS Class	No. Sites	Mean ln MC at 100 RCI	Mean ln MC at 200 RCI
CH	6	3.620	3.341
CL	14	3.226	3.058
ML	8	3.392	3.249
CL-ML	5	3.117	2.949
All classes	33	3.322	3.139

Only four classes were included; data were not available for the MH, OL, SM, and SC-SM soils. The data suggest a tendency for values of the RCI-MC coefficients to decrease with decreasing plasticity. Pooled standard deviations from class means of ln MC at 100 RCI and ln MC at 200 RCI were 0.144 and 0.184, respectively; equivalent arithmetic values are 4.0% and 4.4% MC, respectively. Results for the two classification systems were approximately the same.

66. Individual soil properties. Regression analysis techniques were used to establish relations between the RCI-MC coefficients and soil properties; properties considered were the same as those considered for CI (paragraph 36). Providing that both relations for a given soil property were significant (5% level), equations, correlation coefficients, and standard deviations from the regression are tabulated below; plots of

basic data and regression lines significant at the 5% level are shown in plates 13-17.

67. The relations between the RCI-MC coefficients and fines content, organic matter content, and dry density were not significant at the 5% level; for sand content, only the relation with ln MC at 200 RCI was significant. The lack of relations for sand, fines, and organic matter content was not considered to be conclusive because the range of values for each property was small. A possible explanation of why little of the variation in the RCI-MC coefficients was associated with dry density is presented in paragraph 37.

68. Five of the nine pairs of relations (clay and silt contents, liquid and plastic limits, and plasticity index) were significant at the 1% level. Relations with all properties except silt content had positive slopes; relations with silt content had negative slopes. Slopes and relative positions of the relations indicate that at a given MC, increases of CI are associated with increases in plasticity and decreases in grain size. As shown in plate 16, for example, at an MC of 30% the RCI increases from 100 to 200 as plasticity index increases from approximately 25 to 49.

69. Plates 13-16 show that the relations of silt and clay contents, liquid and plastic limits, and plasticity index to MC at 200 RCI have flatter slopes than the relations to MC at 100 RCI. From this and the position of the two regression lines with respect to each other, it can be concluded that each of the properties is related to the arithmetic slope of the

RCI-MC relations, at least between the 100- and 200- RCI levels. Slopes of RCI-MC relations become flatter with increases in plasticity and decreases in grain size. As an example, for soils having a clay content of 20% (plate 14), an increase in RCI from 100 to 200 is associated with an average MC loss of approximately 4% (i.e. 27% MC minus 23% MC); for an equivalent strength gain for soils having a clay content of 60%, an average MC loss of approximately 9% (43% MC minus 34% MC) is indicated. The linear relation between MC at 100 RCI and MC at 200 RCI, computed using reduced major axis analysis techniques, is shown in plate 18. Results indicate that arithmetic slopes of RCI-MC relations between the 100- and 200-RCI levels tend to become flatter with an increase in the moisture-holding capacity of the soil.

70. Slopes of the relations between the RCI-MC coefficients and silt content were, as expected, negative. As noted in paragraph 64, it is difficult to obtain RCI data on sandy soils. For low-silt-content soils, RCI data are most readily obtained for soils with low sand contents and high clay contents. Values of the RCI-MC coefficients would tend to be relatively high.

71. Considering both RCI-MC coefficients, relations with liquid limit were better than with any other individual soil property analyzed. Standard deviations from the regression for ln MC at 100 RCI and ln MC at 200 RCI were 0.106 and 0.153, respectively; comparable arithmetic values at the mean logarithmic values of the RCI-MC coefficients are 2.9% MC and 3.5% MC, respectively. Estimations were better with liquid limit, plastic limit, or plasticity index than with USCS class means (paragraph 65).

72. Grouped soil properties. Multiple regression analyses were made to establish relations between the RCI-MC coefficients and groups of soil properties. Procedures followed and assumptions made were the same as those for the CI-MC coefficients discussed in paragraphs 36 and 43. Results are summarized in the following tabulation.

73. As shown in the tabulation, partial regression coefficients of liquid limit and plastic limit generally were consistent between groups of soil properties in terms of sign and magnitude. This may indicate a natural association between these properties and the RCI-MC coefficients.

74. The best relations included properties associated with plasticity. Grain size characteristics may contribute little to estimation accuracies. This is indicated by the fact that relations with sand, silt, and clay contents were by far the poorest of those derived, and by the fact that the addition of fines content to relations with the Atterberg limits had almost no effect.

75. Shown below is a summary of estimation accuracies obtained with the USCS, liquid limit, and groups of soil properties. Included are standard deviations of the RCI-MC coefficients in logarithmic terms and equivalent arithmetic values.

	Standard Deviation			
	MC at 100 RCI		MC at 200 RCI	
Classification System or Soil Property(ies)	ln	Arithmetic Equivalent	ln	Arithmetic Equivalent
USCS	0.144	4.0	0.184	4.4
LL	0.106	2.9	0.153	3.5
LL and PL	0.076	2.1	0.123	2.8
Sand, silt, and clay	0.146	4.0	0.175	4.0
Fines, LL, PL, and PI	0.075	2.0	0.124	2.8
LL, PL, PI, and density	0.070	1.9	0.014	2.6

76. Relations with liquid limit, plastic limit, plasticity index, and density were slightly better than with any other group of soil

properties tested, and were markedly better than with the USCS or the best individual property tested (liquid limit). With respect to accuracy of estimations, relations incorporating the soil properties used to define classes of the USCS (i.e. fines content, liquid and plastic limits, and plasticity index) were appreciably better than relations for the system itself. This indicates that a better classification system could be devised based on the same defining soil properties.

RCI-soil property relations

77. Procedures for expressing CI in terms of soil properties and MC using CI-MC coefficient-soil property relations were presented in paragraph 48. In a like manner RCI-soil property relations can be derived.

$$Y = Y_1 - \frac{(Y_1 - Y_2)(X_1 - X)}{X_1 - X_2}$$

where

$Y = \ln \text{RCI}$

$Y_1 = \ln 100 \text{ RCI} = 4.60517$

$Y_2 = \ln 200 \text{ RCI} = 5.29832$

$X = \ln \text{MC}$

$X_1 = \ln \text{MC at } 100 \text{ RCI}$

$X_2 = \ln \text{MC at } 200 \text{ RCI}$

Therefore

$$\ln \text{RCI} = 4.605 + \frac{0.693(\ln \text{MC at } 100 \text{ RCI} - \ln \text{MC})}{\ln \text{MC at } 100 \text{ RCI} - \ln \text{MC at } 200 \text{ RCI}}$$

An analysis of changes in RCI associated with changes in values of some of the soil properties used in this study was made. At three levels of MC (20%, 30%, and 40%) RCI values were computed for various combinations of values of soil properties included in each of two groups: (a) USDA sand, silt, and clay contents and (b) Atterberg liquid limit, plastic limit, and plasticity index. Isolines of RCI are shown on textural triangles and plasticity charts in plates 19 and 20, respectively.

78. The data in plates 19 and 20 show that for any given combination of soil properties tested RCI decreases with an increase in MC. Plate 19

indicates that there are interacting effects on RCI between MC and the USDA soil separates. At the 30% and 40% MC levels RCI changes are associated almost entirely with changes in clay content, RCI increasing with an increase in clay content. At the 20% MC level, however, RCI increases are associated with both increases in clay content and decreases in sand content.

79. The data in plate 20 show that RCI changes at high liquid limits (i.e. greater than approximately 50) are associated primarily with changes in plastic limit, RCI increasing with an increase in plastic limit. At low liquid limits, however, RCI tends to increase with increases in both plastic limit and liquid limit. The lowest RCI values at a given MC are associated with low plastic and liquid limit values.

Remolding Index (RI)

80. Analyses pertaining to RI are presented herein. Procedures followed were similar to those used in analyses of CI and RCI except that a method for adjusting RI for changes in MC could not be derived directly from the basic data. Some general conclusions regarding the changes in RI associated with changes in MC were made indirectly, however, by using previously derived CI and RCI relations. This was possible because of the relation that exists between the strength measures, i.e. RCI = (CI)(RI).

RI-MC relations

81. For the sake of consistency, RI values corresponding to 300+ CI values were excluded from RI-MC relation derivations (see paragraphs 13 and 54). The data that remained for analysis were the same as those listed in paragraph 55. Of the 95 sites 68 (72%) had a sufficient number of observations (more than two) to statistically derive RI-MC relations; 38 (56% of the 68 sites) had fewer than ten observations.

82. Selection of equation form. A logarithmic equation form was selected for use in attempting to relate RI to MC. Both linear and curve forms had been used in previous studies.[1b,2,3,5-7] Examination of basic data plots like those shown in plate 21 did not indicate that the relation was other than linear. However, as shown below, the use of logarithmic CI-MC and RCI-MC equation forms resulted in the selection of a logarithmic RI-MC equation form.

$$RI = \frac{RCI}{CI}$$

$$\ln RI = \ln RCI - \ln CI$$

$$\ln RCI = a_1 + b_1(\ln MC)$$

$$\ln CI = a_2 + b_2(\ln MC)$$

$$\ln RI = a_1 - a_2 + (b_1 - b_2)(\ln MC)$$

$$\ln RI = a + b\ (\ln MC)$$

83. Derivation of relations. Reduced major axis analysis techniques were used in deriving RI-MC relations. Numbers of observations, correlation coefficients, levels of significance (1% and 5%), and equations are shown in table 3. For the 68 sites with three or more observations, only 18 (26%) of the relations were significant at the 5% level and only 7 (10%) were significant at the 1% level. The relatively small percentage of significant relations suggested that a general method for adjusting RI for changes in MC could not be derived directly from the data.

RI coefficient

84. Selection of an RI coefficient. The use of a constant value of RI for each site was considered appropriate since a consistent method for adjusting RI for changes in MC was not apparent. Statistically the best estimator for a set of univariate data is the mean. For this reason, mean RI ($\overline{RI}$) was selected as the RI coefficient for use in further analysis; values are included in table 3.

85. Selection of sites for further analyses. Before conducting analyses relating $\overline{RI}$ to soil properties it was considered necessary to select sites with reliable $\overline{RI}$ values. For this purpose, the standard deviation of the mean ($s_{\bar{y}}$) was considered to be the most meaningful criterion that could be used. This statistic is, in fact, a measure of reliability of a sample mean, reliability being in terms of closeness to the population mean with a 68% probability. A sample consisting of a minimum of two observations is required to compute a standard deviation of the mean. A summary of $s_{\bar{y}}$ values with two or more RI observations is tabulated below.

$s_{\bar{y}}$	No. Sites	$s_{\bar{y}}$	No. Sites
0.00	1	0.02	17
0.01	9	0.03	11

(Continued)

$s_{\bar{y}}$	No. Sites	$s_{\bar{y}}$	No. Sites
0.04	12	0.08	0
0.05	6	0.09	6
0.06	5	0.10	2
0.07	2	≥0.11	5

The 13 sites with $s_{\bar{y}}$ values of 0.08 or greater were rejected from further consideration; this choice was arbitrary, although, as indicated by the tabulation above, 0.08 seems to have separated sites of relatively low and high variations in RI. All sites with four or less observations were also excluded because this criterion was used in selecting sites for establishing RCI relations. The remaining 52 sites were used for further analysis; they are indicated by the symbol † in table 3.

RI coefficient-
<u>soil property relations</u>

86. Logarithmic values of the RI coefficients were used in deriving relations to eliminate the possibility of estimating negative $\overline{RI}$ values. As in the case of CI and RCI, three ways of relating the RI coefficient to soil differences were explored: (a) by soil classes, (b) by individual soil properties, and (c) by groups of soil properties.

87. <u>Soil classes.</u> The effectiveness of soil classes for estimating $\overline{RI}$ was determined on the basis of the pooled standard deviations for each of the classification systems. Average values of the RI coefficient for USDA soil textural classes are tabulated below. The SCL, SC, LS, S, and Si classes were not represented or were represented by only one site and, therefore, are not included.

USDA Soil Class	No. Sites	Mean ln $\overline{RI}$	USDA Soil Class	No. Sites	Mean ln $\overline{RI}$
C	6	-0.024	SiL	32	-0.642
SiC	2	-0.024	L	5	-0.358
SiCL	2	-0.198	SL	2	-0.942
CL	2	-0.134	All classes	51	-0.492

Although seven classes were represented, the numbers of sites per class

were low with the exception of the C, SiL, and L classes. Classes are arranged in approximate order of increasing grain size. The data used indicate that $\overline{RI}$ tends to increase with a decrease in grain size. The pooled standard deviation from class means was 0.321; the equivalent arithmetic value at the mean logarithmic value of $\overline{RI}$ is 0.20 RI unit.

88. Average values of the RI coefficients by USCS classes are shown below. The OL, OH, SC-SM, MH, and SM classes were not represented or were represented by only one site and are, therefore, not included.

USCS Soil Class	No. Sites	Mean ln $\overline{RI}$	USCS Soil Class	No. Sites	Mean ln $\overline{RI}$
CH	10	-0.051	CL-ML	7	-1.165
CL	21	-0.367	All classes	50	-0.482
ML	12	-0.646			

The classes are arranged in order of decreasing plasticity. The data indicate that $\overline{RI}$ increases with increases in plasticity. The pooled standard deviation from class means was 0.214; the equivalent arithmetic value at the mean logarithmic value of $\overline{RI}$ is 0.13 RI unit.

89. Individual soil properties. Regression analyses were used to establish relations between $\overline{RI}$ and soil properties. Properties considered were the same as those considered for CI and RCI (paragraph 36). Significant relations (5% level) and corresponding correlation coefficients and standard deviations from the regression are tabulated below; basic data and regression lines significant at the 5% level are shown in plates 22-24.

[illegible]

Soil Property (X)	Low Value	High Value	No. Observations	Correlation Coefficient	Relation ln $\overline{RI}$ =	Standard Deviation from Regression	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--
[illegible]		[illegible]	[illegible]	[illegible]	--	--	--

[illegible]

90. Relations between $\overline{RI}$ and sand content, fines content, plastic limit, organic matter content, and dry density were not significant. The range of organic matter content values was small; the lack of a significant relation was not, therefore, considered to be conclusive. For the other soil properties, ranges of values were reasonably large; results indicate, therefore, that little of the variation in $\overline{RI}$ is associated with the properties.

91. Relations between $\overline{RI}$ and silt content, clay content, liquid limit, and plasticity index were significant at the 1% level. With the exception of silt content, regression coefficients for these soil properties were all positive. The data, therefore, indicate that $\overline{RI}$ increases with an increase in plasticity and a decrease in grain size. As shown in plate 24, for example, $\overline{RI}$ values of approximately 0.40 and 1.00 are associated with plasticity index values of 4 and 47, respectively. The relation of $\overline{RI}$ with plasticity index was better than with any other soil property tested. The standard deviation from the regression was 0.227; the equivalent arithmetic value at the mean logarithmic value of $\overline{RI}$ is 0.14 RI unit.

92. <u>Grouped soil properties.</u> Multiple regression analysis techniques were used to derive relations between $\overline{RI}$ and groups of soil properties. Procedures followed and assumptions made were the same as those for CI (paragraphs 36 and 43). A summary of the results is shown in the following tabulation.

93. Results show that the best three relations included soil properties associated with plasticity (i.e. Atterberg limits). Relations

including soil properties associated with both grain size and plasticity (first and fourth listed) were comparable to the relation based only on plasticity properties (fifth listed). However, the poorest relation (second listed) was based only on grain size characteristics.

94. Shown below is a summary of $\overline{RI}$ estimation accuracies obtained with the USCS and some of the individual and groups of soil properties. Included are standard deviations of ln $\overline{RI}$ and equivalent arithmetic values at the mean logarithmic value of $\overline{RI}$.

Classification System or Soil Property(ies)	Standard Deviation ln	Standard Deviation Arithmetic Equivalent
USCS	0.214	0.13
PI	0.227	0.14
Silt, clay, and PI	0.108	0.07
Sand, silt, and clay	0.131	0.08
Fines, LL, PL, and PI	0.105	0.06

95. The relations with fines content, liquid limit, plastic limit, and plasticity index (the last shown) were better than those with any other group of soil properties tested. Estimation with this group of soil properties was considerably better than that with the USCS or the best individual soil property tested (plasticity index). With respect to the accuracy of estimation, the relation based on soil properties used in differentiating USCS fine-grained soils was appreciably better than for the system itself. This indicates that the classification criteria of the system could be improved with respect to $\overline{RI}$.

RI-soil property relations

96. Although the effect of MC on RI could not be established directly from the basic data (paragraph 83), it was possible to do so by using previously derived CI-MC and RCI-MC coefficient relations. This indirect approach is discussed in the following paragraphs.

97. As noted in paragraph 82, RI can be expressed in the following manner:

$$\ln RI = \ln RCI - \ln CI$$

By substituting the equation for CI and RCI shown in paragraphs 48 and 77, respectively, RI can be expressed in terms of CI- and RCI-MC coefficients, i.e.,

$$\ln RI = -0.693 + \frac{0.693\ (\ln MC \text{ at } 100\ RCI - \ln MC)}{\ln MC \text{ at } 100\ RCI - \ln MC \text{ at } 200\ RCI} - \frac{0.405(\ln MC \text{ at } 200\ CI - \ln MC)}{\ln MC \text{ at } 200\ CI - \ln MC \text{ at } 300\ CI}$$

By further substituting CI-MC and RCI-MC coefficient-soil property relations, RI can be expressed solely in terms of one or more soil properties and MC.

98. An analysis of changes in RI associated with changes in values of MC and some soil properties was made. At three MC levels (20%, 30%, and 40%) RI values were computed for combinations of values of soil properties included in each of two groups: (a) USDA sand, silt, and clay contents and (b) Atterberg liquid limit, plastic limit, and plasticity index. These data were plotted on USDA textural triangles and plasticity charts and iso-lines of RI were drawn. Results are shown in plates 25 and 26.

99. In deriving CI and RCI relations, data from different sites were used. The associated differences in soil properties (CI can be measured under firmer soil conditions than can RCI; therefore soils from which CI data are obtained are often sandier and/or drier) result in the two sets of relations not being exactly comparable. Any resultant inconsistencies in estimated CI and RCI values would, in all probability, be magnified when a ratio of the two strength measures is taken. Since RI is, in effect, a ratio (RI = RCI/CI) caution should be exercised in interpreting the data shown in plates 25 and 26. In view of this, the discussion that follows is somewhat general.

100. The data shown in plate 25 indicate that at a given MC level, increases in RI are primarily associated with increases in clay content although at the 20% MC level sand content also appears to be an associated factor. Consistent with results of past studies, the data also indicate that low RI values are associated with high silt contents at high moisture levels.

101. Of interest are the apparent effects of MC on RI; estimated RI for the three levels of MC at several different combinations of sand, silt, and clay contents are tabulated below.

Sand %	Silt %	Clay %	MC %	Estimated RI	Sand %	Silt %	Clay %	MC %	Estimated RI
10	80	10	20	1.07	30	60	10	20	0.95
			30	0.20				30	0.39
			40	0.06				40	0.22
10	70	20	20	1.06	30	50	20	20	1.1[illegible]
			30	0.48				30	0.[illegible]
			40	0.28				40	0.43
10	60	30	20	1.04	30	40	30	20	1.4[illegible]
			30	0.7[illegible]				30	0.91
			40	0.62				40	0.[illegible]
10	50	40	20	1.07					
			30	1.00					
			40	0.94					

In all cases results indicate that RI increases with a decrease in MC. This is in agreement with results of the RI-MC reduced major axis analyses (see table 3). Of the 68 sites for which analyses were made 53 of the correlation coefficients were negative; of the 18 relations significant at the 5% level all but one had a negative slope.

102. The data in plate 26 indicate that at the 20% MC level increases in RI are associated primarily with increases in plastic limit. At the higher MC levels studied and at relatively high liquid limits this again appears to be the case. However, at high MC levels and at liquid limits of less than about 50, increases in RI appear to become more closely associated with increases in liquid limit. The lowest estimated RI values occur at the lowest liquid limits tested irrespective of MC.

103. Estimated RI for the three MC levels at several different combinations of Atterberg limit values are tabulated below.

PL	LL	PI	MC %	Estimated RI	PL	LL	PI	MC %	Estimated RI
20	30	10	20	0.83	20	40	20	20	1.0[illegible]
			30	0.32				30	0.[illegible]
			40	0.16				40	0.45

(Continued)

PL	LL	PI	MC %	Estimated RI
20	50	30	20	1.10
			30	0.90
			40	0.78
20	60	40	20	0.97
			30	1.01
			40	1.04
25	30	5	20	1.64
			30	0.40
			40	0.15
25	40	15	20	1.90
			30	0.80
			40	0.44
25	50	25	20	1.78
			30	1.05
			40	0.72
25	60	35	20	1.52
			30	1.12
			40	0.91
25	70	45	20	1.22
			30	1.09
			40	1.00

For almost all combinations of Atterberg limit values tested, RI increases with a decrease in MC. As noted in paragraph 101, this is in agreement with results of the RI-MC reduced major axis analyses. The data listed above also indicate that RI-MC slopes become flatter with increases in liquid limit.

PART III: PREDICTION OF SOIL STRENGTH

104. The relations presented in Part II of this report are of general interest in that they quantitatively define changes in soil strength associated with changes of several commonly measured soil properties. Of additional importance, however, is that the relations can be used to predict soil strength providing that a MC value is available.

105. Two general methods for predicting either CI or RCI are presented herein. One method is based on CI-MC (or RCI-MC, as the case may be) coefficient-soil property relations; in addition to MC, soil property values are required as input. The other method is based on the relation that exists between coefficients (i.e., MC at 200 CI versus MC at 300 CI or MC at 100 RCI versus MC at 200 RCI) as noted in paragraphs 39 and 69. In addition to an MC at which a soil strength value is to be predicted, a representative CI-MC (or RCI-MC) observation is required as input; however, the method is independent of soil property data. Predictions are evaluated on the basis of those sites used in the derivation of relations.

Cone Index

Predictions based on soil property data

106. As shown in paragraph 48, a CI-MC relation can be estimated using the following equation.

$$\ln CI = 5.298 + \frac{0.405\ (\ln MC \text{ at } 200\ CI - \ln MC)}{\ln MC \text{ at } 200\ CI - \ln MC \text{ at } 300\ CI}$$

By substituting CI-MC coefficient-soil property relations, CI can be expressed solely in terms of soil properties and MC. If, for example, the relations of the coefficients with clay content (shown in tabulation, paragraph 36) are substituted the equation above becomes:

$$\ln CI = 5.298 + \frac{0.956 + 0.1012\ (\ln \%\ clay) - 0.405 \ln MC}{0.671 - 0.1460\ (\ln \%\ clay)}$$

For a soil with a clay content of 10% the equation becomes

$$\ln CI = 8.847 - 1.209 \ln MC$$

With an input MC value this equation can be used to predict CI. In a like manner CI predictions can be made with knowledge of the USDA textural or USCS class, other individual soil properties, or groups of soil properties.

107. For presentation and discussion herein two predictions of CI were made, one on the basis of USDA sand, silt, and clay contents and the other on the basis of Atterberg liquid limit, plastic limit, and plasticity index. These two particular soil property groups were selected because they are probably the most readily obtainable from indirect sources, i.e., maps, soil surveys, and other forms of literature. Relations of the CI-MC coefficients with these soil property groups were all highly significant, those with the USDA soil separates having the highest multiple correlation coefficients.

108. As previously noted, evaluations were made with the sites used in deriving the CI-MC coefficient relations, 72 sites for relations with the USDA soil separates and 67 sites for the relations with the Atterberg limits. Logarithmic CI values were predicted using MC values corresponding to six levels of specific CI: 50, 100, 150, 200, 250, and 300. Standard deviations from the mean and average algebraic deviations, both in logarithmic terms, were then computed for each of the above-listed specific CI levels. Equivalent arithmetic values were then determined, plotted on graph paper, and smooth curves were drawn through the points. Results are shown in plate 27.

109. Prediction accuracies were not good. For predictions based on USDA soil separates, standard deviations ranged from about 34, i.e. $\frac{+55 + |-13|}{2}$, at a specific CI level of 50 to about 125 at a specific CI level of 300; based on the Atterberg limits, corresponding deviations were about 27 and 133. The decrease in prediction accuracy with an increase in specific CI can be attributed to the fact that the slopes of CI-MC relations become steeper as the CI level increases (see plate 2). The data in plate 27 also show that, on the average, predictions were slightly high at

low levels of specific CI (i.e. <200). This algebraic trend could be easily corrected, but the resultant decreases in standard deviation values would be negligible.

110. Standard deviations from the mean of measured CI values by 10-unit increments of specific CI to a specific CI level of 210 were computed (computations for higher specific CI levels could not be made because 300+ measured values would have been included, and their effects could not, of course, be precisely determined). A summary of measurement and prediction accuracies is shown below.

	Standard Deviation from Mean at Specific CI Levels of			
	50	100	150	200
CI measured	8	18	27	35
CI predicted on basis of USDA soil separates	34	38	51	64
CI predicted on basis of Atterberg limits	27	30	44	64

In general, prediction deviations are about twice as large as measurement deviations. It should be noted, moreover, that the measurement deviations shown are from sites for which a high correlation existed between CI and MC (see paragraph 22); for all sites in general, measurement error* would thus be greater than indicated.

111. Coefficients of determination for the CI-MC coefficient relations indicate that between 63% and 74% of the variance of the CI-MC coefficients, e.g., the variance of the position of the CI-MC relations, is explained by the USDA soil separates. A question arises as to what other soil properties or characteristics could be used to account for the unexplained variation.

112. Perhaps the most important factor is soil structure as the term is used in the field of agriculture; i.e., the arrangement of primary particles and secondary particles (aggregates) into compound particles (peds)

* The term "measurement error" as used in this paragraph includes error attributable to several sources, i.e., natural variation, operator, instrument, etc.

which are separated from adjoining peds by surfaces of weakness. Primary and secondary particles are held together by binding agents which impart strength to the soil. Descriptors of soil structure, particularly quantitative descriptors, that could be used in a study such as this one are not presently available.

113. The effects of clay and organic matter contents have been assessed herein. Of equal or perhaps greater importance, in all probability, are the electrochemical properties of these soil materials, i.e., the cation exchange capacities, adsorbed cations, clay mineralogy, etc. A study of these factors might well lead to a more fundamental understanding of soil strength phenomena.

114. Other soil characteristics that might be examined profitably include soil moisture-tension relations, specific surface, and activity. Values of the above-listed characteristics relate closely to what are considered to be the more fundamental soil properties. MC's at given tensions (particularly for tensions of less than about 3 atm) determined from undisturbed samples are indicative of a soil's structural characteristics. Specific surface is a reflection of the grain size distribution of a soil including particle sizes far below the 2-micron limit generally observed in settlement analyses. The contribution of the clay minerals to the behavior of a soil is reflected to some extent by activity.

115. Consideration should also be given to the possible modification of some existing soil test procedures; tests should reflect characteristics of a soil in its entirety and its natural state. For example, soil samples should not be excessively dried (i.e., dried below the lowest natural moisture level that occurs in the field) before testing. Further, the USDA practice of screening out all materials larger than 2 mm prior to establishing grain size distribution curves would seem inappropriate insofar as engineering studies in general are concerned.

Predictions based on a
<u>measured CI-MC observation</u>

116. A method for estimating a CI-MC relation was developed from the relation that exists between the two CI-MC coefficients shown in plate 8. CI can be predicted for any given MC of interest provided that a

representative (i.e., representative of the area in question) CI-MC observation is available.

117. MC at 300-CI values of 2 through 33 were substituted into the equation shown in plate 8 and corresponding values of MC at 200 CI were computed. Lines passing through corresponding points were then drawn on logarithmic graph paper as shown in plate 28. By plotting a representative CI-MC observation on the graph an estimated CI-MC relation is obtained (interpolation may be required).

118. In evaluating the method, the mean logarithmic values of measured CI and MC (observations with 300+ CI values were excluded) were determined for the 72 sites used in deriving CI relations. Arithmetic equivalents of the mean logarithmic values were then determined, plotted on a graph like that shown in plate 28, and estimated CI-MC relations established. Prediction accuracies were assessed in the same manner as that described in paragraph 108; results are shown in plate 29.

119. Standard deviations ranged from about 20, i.e. $\frac{+36 + |-4|}{2}$, at a specific CI level of 50 to about 91 at a specific CI level of 300. A summary of accuracies of measurements (see paragraph 110), predictions based on Atterberg limits, and predictions based on site-mean CI-MC observations is shown below.

	Standard Deviation from Mean at Specific CI Levels of			
	50	100	150	200
CI measured	8	18	27	35
CI predicted on basis of Atterberg limits	27	30	44	64
CI predicted on basis of site-mean CI-MC observations	20	23	30	36

Predictions based on a representative CI-MC observation are much better than those based on soil properties and approach the accuracy of measurements at intermediate CI levels.

120. A prediction method based on a representative CI-MC observation is obviously limited; necessary information could not generally be obtained from indirect sources. Also, representative CI-MC observations may

occasionally fall below the lines shown in plate 28 (5 of the 72 values tested did) in which case the envelope curve formed by the intersecting lines must be used for prediction purposes.

Rating Cone Index

121. Methods used to predict RCI and procedures used in evaluating the methods were essentially the same as those used for CI. Consequently, the discussion that follows is somewhat abbreviated.

Predictions based on soil property data

122. In a manner analogous to that discussed in paragraph 106, RCI can be expressed in terms of a soil property or properties. On the basis of clay content (see relations shown in paragraph 66), for example, the equation is as follows:

$$\ln RCI = 4.605 + \frac{2.123 + 0.008(\%\ clay) - 0.693 \ln MC}{0.149 + 0.002(\%\ clay)}$$

For a soil with a clay content of 10% the equation becomes

$$\ln RCI = 17.658 - 4.101 \ln MC$$

With an input MC value this equation can be used to predict RCI.

123. Two predictions of RCI were made, one on the basis of the USDA separates and the other on the basis of the Atterberg limits. Prediction evaluations were made with the 33 sites used in deriving RCI-MC coefficient relations. Deviations between estimated RCI and specific RCI were computed at seven levels of specific RCI (25, 50, 100, 150, 200, 250, and 300) in the same manner as that for CI (see paragraph 108). Results are portrayed graphically in plate 30.

124. For predictions based on the USDA soil separates, standard deviations ranged from about 21, i.e. $\frac{+29 + |-13|}{2}$, at a specific RCI of 25 to about 194 at a specific RCI level of 250; based on the Atterberg limits, corresponding deviations were about 19 and 140. Predictions were poor

except for those based on the Atterberg limits at low (<100) specific RCI values. The extremely poor prediction accuracies at high levels of specific RCI are probably attributable to the steepness of RCI-MC relations. As shown in plate 12, for example, a moisture content change of 1% at a specific RCI level of 300 corresponds to an RCI change of more than 40 units. Average algebraic deviations of the predictions were insignificant.

125. Standard deviations of measured RCI values were computed in the same manner as that for CI (see paragraph 110). A summary of measurements and prediction accuracies is shown below.

	Standard Deviation from Mean at Specific RCI Levels of				
	25	50	100	150	200
RCI measured	9	14	25	33	38
RCI predicted on basis of USDA soil separates	21	33	57	92	138
RCI predicted on basis of Atterberg limits	19	18	27	54	94

Data included in the tabulation above again show that RCI predictions based on USDA soil separates are poor. When compared with measurement deviations below the 150 specific RCI level, deviations from predictions based on Atterberg limits do not appear to be excessive; in fact, accuracies are about the same at the 100 specific RCI level. Of interest is the fact that at a given level of specific CI or RCI, RCI measurement accuracy is markedly poorer than is CI measurement accuracy.

126. The multiple correlation coefficient for the relation between MC at 100 RCI and the Atterberg limits is 0.946 (see tabulation at top of page 27), and the coefficient of determination is 0.895. Consequently, the unexplained variance (10%) is associated with a standard deviation of 27 RCI units. Viewed in this manner, results are particularly disturbing; the correlation is better than could be expected, or even hoped for, but still not suitable for accurately predicting the performance of a given vehicle (see tabulation in paragraph 1e). A better understanding of RCI might well be gained by studying the influence of the soil properties discussed in paragraphs 113-115.

Predictions based on a
measured RCI-MC observation

127. A method for predicting RCI was developed from the relation that exists between the two RCI-MC coefficients (see plate 18) in the same manner as that for CI discussed in paragraphs 116 and 117. By plotting a representative RCI-MC observation on the graph shown in plate 31 an estimated RCI-MC relation can readily be established.

128. Prediction accuracies are shown in plate 32. Standard deviations ranged from about 11, i.e. $\frac{+16 + |-6|}{2}$, at a specific RCI of 25 to about 137 at a specific RCI level of 250. A summary of measurement and prediction accuracies is shown below.

	Standard Deviation from Mean at Specific RCI Levels of				
	25	50	100	150	200
RCI measured	9	14	25	33	38
RCI predicted on basis of Atterberg limits	19	18	27	54	94
RCI predicted on basis of site-mean RCI-MC observations	11	15	23	51	90

At specific RCI levels of 100 or less the accuracies of measurements and predictions based on representative RCI-MC observations are about the same. At higher levels of specific RCI, accuracy of predictions based on a representative RCI-MC observation decreases rapidly, approximating that of predictions based on the Atterberg limits.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

129. The basic data used in this study were limited in two major respects: (a) all were taken from soils within the temperate zone (specifically, from the continental United States) and (b) all were taken from soils with significant amounts of fines (i.e., the strength of any given soil used in the analyses was not entirely due to internal friction alone). Conclusions are, of course, restricted to the confines of these limitations.

130. Conclusions are listed below. For the convenience of the reader, the principal paragraphs, tables, and plates supporting each conclusion are noted.

a. For all soils CI and RCI decrease with an increase in MC (paragraphs 21, 51, 52, and 78, tables 1 and 2, and plates 9, 10, 19, and 20). For almost all soils RI decreases with an increase in MC (paragraphs 101 and 103, table 3, and plates 25 and 26).

b. Arithmetic slopes of CI-MC relations are approximately parallel regardless of soil characteristics (paragraph 30 and plate 8). Arithmetic slopes of RCI- and RI-MC relations tend to become flatter with decreases in grain size or increases in plasticity (paragraphs 69, 101, and 103 and plates 18, 25, and 26).

c. Both CI and RCI are quite sensitive to changes in MC. For example, at the 200-CI and 200-RCI levels a change in MC of +1.0% corresponds to an average change of -16 and -30 CI and RCI units, respectively (paragraphs 30 and 62 and plates 2 and 12). The sensitivity of RI to changes in MC decreases with decreases in grain size or increases in plasticity, apparently to a point where RI is not associated with MC (paragraphs 101 and 103 and plates 25 and 26).

d. Relations significant at the 5% level exist between the coefficients and the following individual soil properties:

CI-MC Coefficients	RCI-MC Coefficients	RI Coefficient
USDA sand	USDA silt	USDA silt
USDA clay	USDA clay	USDA clay
USCS fines	Liquid limit	Liquid limit

(Continued)

CI-MC Coefficients	RCI-MC Coefficients	RI Coefficients
Liquid limit	Plastic limit	Plasticity index
Plastic limit	Plasticity index	
Plasticity index		

Little correlation exists between dry density and any of the coefficients (paragraphs 36, 37, 40, 66, 67, 89, and 90 and plates 3-7, 13-17, and 22-24).

e. Values of CI- and RCI-MC coefficients (MC at the 200- and 300-CI levels and MC at the 100- and 200-RCI levels, respectively) increase with a decrease in grain size or an increase in plasticity (paragraphs 34-36 and 64-66 and plates 3-6 and 13-16). Values of the RI coefficient (site mean RI) increase with a decrease in grain size or an increase in plasticity (paragraphs 87-89 and plates 22-24).

f. Interacting effects on CI, RCI, and RI exist between MC and the USDA soil separates. At a relatively high MC level (40%), changes in all three strength parameters are associated almost entirely with changes in clay content. With decreasing MC, however, changes in the strength parameters tend to become more closely associated with sand content; at the 20% MC level, sand content is either a primary or the dominant associated factor (paragraphs 50, 78, and 100 and plates 9, 19, and 25).

g. Interacting effects on CI, RCI, and RI exist between MC and the Atterberg limits. At a given MC level, plastic limit is a factor consistently associated with the three strength parameters; it is of either primary or secondary importance. Liquid limit is a factor of primary, secondary, or little importance depending upon the strength parameter and moisture level in question (paragraphs 52, 79, and 102 and plates 10, 20, and 26).

h. With an input MC, CI or RCI can be predicted with a knowledge of USDA textural classification system class or USCS class, one of several individual soil properties, one of several groups of soil properties, or a representative CI-MC (or RCI-MC) observation. Prediction accuracies, however, are not good. Based on the Atterberg limits, for example, standard deviations of predicted CI ranged from about 27 at a CI level of 50 to about 133 at a CI level of 300; standard deviations of predicted RCI ranged from about 19 at an RCI level of 25 to about 94 at an RCI level of 200 (paragraphs 106, 109, 117, 119, and 124 and plates 27-32).

Recommendations

131. Based on the limitations of basic data used in this study and results of the analyses the following recommendations are made.

a. An additional soil strength study based on field data should be made. Data collected with the 0.2-sq-in. cone penetrometer (maximum reading of 750) would be included. The study would be patterned after the one presented herein with the following important exceptions.

   (1) Measured MC values by increments of measured CI and RCI (perhaps 10 or 20 units) would be related to soil property values. This would (a) eliminate the necessity of using only those data for which reliable CI-MC or RCI-MC relations exist, (b) provide a means for accurately approximating the true equation form(s) describing the CI-MC and RCI-MC relations, and (c) allow incorporation of practically all CI-MC and RCI-MC data available, thus greatly expanding the applicability of derived relations in terms of soil property value ranges and/or regions of the world.

   (2) The feasibility of establishing relations with MC expressed on a volumetric basis would be investigated.

   (3) Contents of soil separates would be based on the total soil.

   (4) Depth at which CI-MC and RCI-MC observations were made would be treated as an additional independent variable.

   (5) Activity would be treated as an additional independent variable to provide some means to account for the effects of clay type.

   The final output of the study would consist of series of textural triangles and plasticity charts on which CI and RCI isolines will be superimposed (see plates 9, 10, 19, and 20). Graphs will be by 1% or 2% increments of MC and probably by increments of activity and other soil properties if they are found to make a significant contribution.

b. A laboratory study of the strength of inorganic clay matrix soils (soils in which particles >0.002 mm are separated by a clay-water system) should be made. The study would be based on the assumption that all the water contained in a clay-matrix soil is associated only with the clay fraction of that soil (for all practical purposes this has been proven true for remolded soils). Prepared soils composed of ground quartz, washed sand, and kaolinite, illite, and bentonite clays (all with the same adsorbed cation type) will be used. The purposes of the study will be to:

(1) test the hypothesis that at a given MC of the clay fraction, the remolded strengths (RCI) of all clay matrix soils containing a given type of clay and adsorbed cations will be equal regardless of the content of clay, (2) test the hypothesis that at a given MC of the clay fraction, the remolded strength (RCI) of clay-matrix soils containing a given type of adsorbed cations will vary with clay type, and (3) gain basic knowledge pertaining to soil strength.

c. A laboratory study of highly organic soils should be made. In this study the assumption would be made that all the water in the soil is associated with the clay and organic matter fractions of the soil. Prepared soils similar to those noted in paragraph 131b would be used except that various types of organic matter (i.e. at various stages of decomposition) would be used to establish the effects of organic matter contents and types on remolded soil strength.

LITERATURE CITED

1. U. S. Army Engineer Waterways Experiment Station, CE, and Forest Service, U. S. Department of Agriculture, "Forecasting Trafficability of Soils," Technical Memorandum No. 3-331, Vicksburg, Miss.

   a. Report 5, "Development and Testing of Some Average Relations for Predicting Soil Moisture," by C. A. Carlson and J. S. Horton, June 1959.

   b. Report 9, "Water Table Study at Crossett, Arkansas," by J. R. Bassett and M. P. Meyer, July 1968.

2. Knight, S. J., "Some Factors Affecting Moisture Content-Density-Cone Index Relations," Miscellaneous Paper No. 4-457, Nov 1961, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

3. Meyer, M. P., "Comparison of Engineering Properties of Selected Temperate and Tropical Surface Soils," Technical Report No. [illegible], June 1966, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

4. Knight, S. J., "Trafficability of Soils; Laboratory Tests to Determine Effects of Moisture Content and Density Variations," Technical Memorandum No. 3-240, 1st Supplement, Mar 1948, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. U. S. Army Engineer Waterways Experiment Station, CE, "Trafficability Predictions in Tropical Soils," Miscellaneous Paper No. [illegible], Vicksburg, Miss.

   a. Report 1, "Four Soils in the Panama Canal Zone," by A. A. Rula and E. S. Rush, Sept 1959.

   b. Report 2, "Puerto Rico Study," by R. A Tobiaski, J. R. Bassett, and E. S. Rush, Feb 1960.

   c. Report 3, "Panama Study No. 2 (October 1961 - September 1963)," by A. R. McDaniel, Aug 1966.

   d. Report 4, "Colombia Study (July 1962 - July 1963)," by A. R. McDaniel, Nov 1967.

   e. Report 5, "Costa Rica Study No. 1 (January 1963 - January 1965)," by A. R. McDaniel, Dec 1967.

   f. Report 6, "Puerto Rico Study No. 2 (March 1962 - November 1963)," by J. G. Kennedy and T. E. Hicks, Nov 1968.

6. Bassett, J. R. et al., "Variation in Trafficability of Four Loess Soils," Miscellaneous Paper No. 4-838, Aug 1966, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

7. U. S. Army Engineer Waterways Experiment Station, CE, "Moisture-Strength Characteristics of Selected Soils in Thailand," Technical Report No. 3-791, Aug 1967, Vicksburg, Miss.

a. Volume I, "Analyses and Application of Data," by J. G. Kennedy, J. G. Collins, and M. H. Smith.

b. Volume II, "Basic Data," by J. G. Collins, M. H. Smith, and J. G. Kennedy.

8. Imbrie, J., "Biometric Methods in the Study of Invertebrate Fossils," Bulletin of the American Museum of Natural History, Vol 108, Article 2, 1956.

9. Miller, R. L. and Kahn, J. S., Statistical Analysis in the Geological Sciences, Wiley, New York, 1962.

10. Liu, T. K. et al., "A Comparison of Clay Contents Determined by Hydrometer and Pipette Methods Using Reduced Major Axis Analysis," Proceedings, Soil Science Society of America, Vol 30, No. 6, Nov-Dec 1966, pp 665-669.

11. "The Influence of Texture on the Moisture Characteristics of Soils," The Journal of Soil Science, Oxford, at the Clarendon Press.

    a. Part I, "A Critical Comparison of Techniques for Determining the Available-Water Capacity and Moisture Characteristic Curve of a Soil," by P. J. Salter and J. B. Williams, Vol 16, No. 1, 1965, pp 1-15.

    b. Part II, "Available-Water Capacity and Moisture Release Characteristics," by P. J. Salter and J. B. Williams, Vol 16, No. 2, 1965, pp 310-317.

    c. Part III, "Quantitative Relationships Between Particle Size, Composition, and Available-Water Capacity," by P. J. Salter, G. Berry, and J. B. Williams, Vol 17, No. 1, 1966, pp 93-98.

    d. Part V, "Relationships Between Particle-Size Composition and Moisture Contents at the Upper and Lower Limits of Available-Water," by P. J. Salter and J. B. Williams, Vol 20, No. 1, 1969, pp 126-131.

12. Broadfoot, W. M. and Burke, H. D., "Soil-Moisture Constants and Their Variation," Occasional Paper No. 166, 1958, U. S. Southern Forest Experiment Station, New Orleans, La.

13. U. S. Department of Agriculture, "Soil Survey Manual," Handbook No. 18, Aug 1951, Washington, D. C.

Table 1

Summary of Cone Index-Soil Moisture Relations

Site No.	No. of Observations	Correlation Coefficient	Equation: ln CI = a + b (ln MC) a	b	CI-MC Coefficients MC at 200 CI %	MC at 300 CI %
1	47	-0.792**	15.453	-3.130	25.7	22.5
2	28	-0.365	--	--	--	--
4	70	-0.221	--	--	--	--
6	62	-0.883**	20.305	-4.466	29.2	26.6
7	51	-0.869**	17.737	-3.780	26.7	24.0
8	55	-0.800**	15.958	-3.225	26.4	23.3
9	13	-0.114	--	--	--	--
10	13	-0.550	--	--	--	--
12	22	-0.950	11.066	-1.958	19.0	15.5
13	15	-0.303	--	--	--	--
14	67	-0.871**	13.112	-2.502	22.7	19.3
15	51	-0.830**	13.952	-2.576	27.7	23.7
16	45	-0.854**	13.531	-2.598	23.8	20.3
17	52	0.017	--	--	--	--
18	43	-0.705**	11.840	-2.064	23.9	19.6
19	19	-0.723**	11.562	-1.901	27.0	21.8
20	48	-0.797**	17.105	-3.708	24.1	21.6
21	40	-0.704**	17.620	-3.815	25.3	22.8
22	15	-0.941**	8.462	-1.236	12.9	9.3
23	14	-0.720**	15.631	-3.269	23.6	20.9
24	6	-0.741	--	--	--	--
25	18	-0.904**	7.486	-0.826	14.1	8.6
26	24	-0.781**	14.573	-2.790	28.1	24.3
27	16	-0.740**	15.290	-3.055	26.3	23.1
28	19	-0.612**	18.302	-4.110	23.7	21.4
29	23	-0.858**	11.694	-2.044	22.9	18.8
30	56	-0.915**	11.361	-1.835	27.2	21.8
31	44	-0.354*	12.221	-2.167	24.4	20.3
32	36	-0.537**	11.681	-1.862	30.9	24.8
33	45	-0.698**	11.718	-2.061	22.5	18.5
34	43	-0.810**	21.437	-4.507	35.9	32.8
35	28	-0.257	--	--	--	--
38	7	-0.973**	7.099	-0.953	6.6	4.3
39	24	-0.708**	14.112	-2.963	19.6	17.1
41	11	-0.479	--	--	--	--
47	6	-0.581	--	--	--	--
48	5	-0.811	--	--	--	--
51	36	-0.927**	7.756	-1.187	7.9	5.6
58	10	-0.895**	14.249	-2.746	26.0	22.5
60	16	-0.174	--	--	--	--
61	21	-0.050	--	--	--	--
62	11	-0.795**	6.839	-0.529	18.4	8.5
67	12	-0.593*	11.247	-1.715	32.1	25.3
71	10	-0.967**	11.585	-2.028	22.2	18.1
72	8	-0.935**	19.729	-4.454	25.5	23.3
74	12	-0.882**	16.780	-3.539	25.6	22.8
75	10	-0.218	--	--	--	--
76	18	-0.694**	12.378	-2.411	18.8	15.9
79	37	-0.647**	8.726	-1.188	17.9	12.7
81	37	-0.920**	8.400	-1.195	14.5	10.3
83	34	-0.567**	9.247	-1.348	18.7	13.9
85	24	-0.857**	9.912	-1.458	11.9	9.0
	19	-0.898**	9.977	-1.449	25.2	19.0
89	15	-0.696**	7.352	-0.640	24.7	13.1
90	19	-0.477*	6.034	-0.329	9.3	2.7
91	20	-0.688**	7.234	-0.915	8.3	5.3
94	11	-0.707*	6.603	-0.485	14.7	6.4
95	13	-0.701**	10.956	-1.791	23.5	18.7
96	14	-0.741**	8.372	-1.050	18.6	12.7
97	16	-0.897**	8.958	-1.205	20.8	14.8
99	22	-0.903**	9.213	-1.270	21.8	15.8
101	10	-0.275	--	--	--	--
102	10	-0.616	--	--	--	--
103	12	-0.844**	7.779	-0.972	12.8	8.4
105	14	-0.844**	8.806	-1.188	19.1	13.6
108	7	-0.528	--	--	--	--
109	11	-0.510	--	--	--	--
110	15	-0.879**	8.935	-1.242	18.7	13.5
112	10	-0.875**	11.509	-1.961	23.7	19.3
114	17	-0.795**	8.611	-1.073	21.9	15.0
115	13	-0.836**	10.476	-1.880	15.7	12.7
116	13	-0.636*	8.522	-0.960	28.6	18.8
117	11	-0.547	--	--	--	--
119	11	-0.522	--	--	--	--
120	13	-0.904**	17.784	-3.898	24.6	22.1
123	21	-0.844**	13.965	-2.934	19.2	16.7
124	14	-0.475	--	--	--	--
125	21	-0.926**	15.515	-3.237	23.5	20.7
126	6	0.497	--	--	--	--
127	8	-0.670	--	--	--	--
128	7	-0.800*	10.813	-1.753	23.2	18.4
129	11	-0.742**	13.251	-2.381	28.2	23.8
130	18	-0.741**	9.737	-1.359	26.2	19.4
131	18	-0.925**	13.520	-2.627	22.8	19.6
132	14	-0.850**	14.685	-2.629	35.5	30.4
133	18	-0.904**	16.434	-3.504	24.0	21.3
134	14	-0.908**	14.106	-2.531	32.4	27.6
135	15	-0.870**	13.816	-2.485	30.7	26.1
136	19	-0.951**	10.885	-1.765	23.6	18.8
150	11	-0.615*	8.355	-1.021	20.0	13.4
151	6	-0.876*	15.592	-3.209	24.7	21.8
152	8	-0.923**	8.994	-1.256	18.8	13.6
153	7	-0.949**	12.812	-2.569	18.6	15.9
155	9	-0.841**	11.136	-1.668	33.1	25.9
156	9	-0.944**	11.049	-1.806	24.1	19.3

* Significant at 5% level.
** Significant at 1% level.

[illegible]

[illegible] Index [illegible] Moisture [illegible]

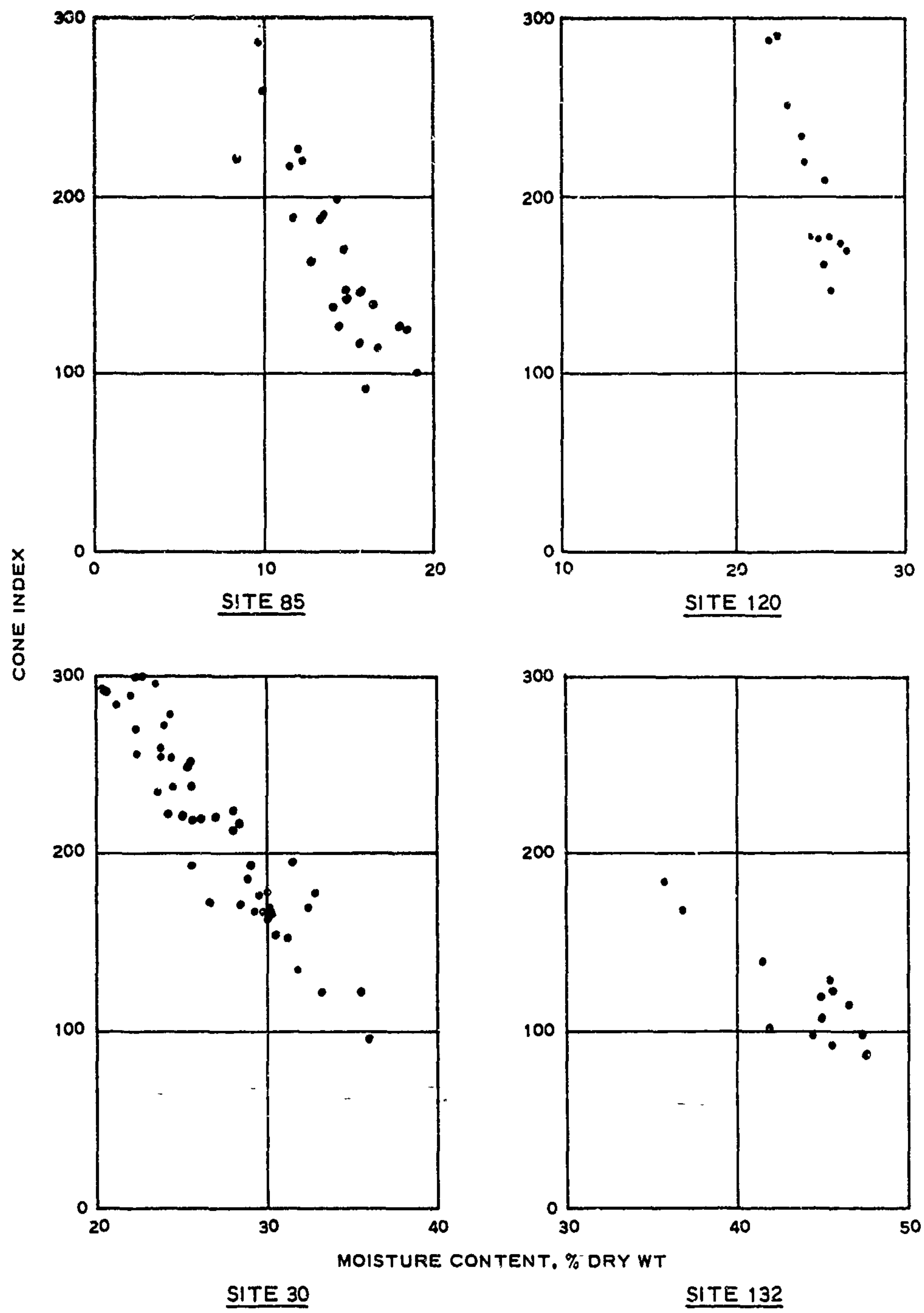
No.	No. of Observations	Correlation Coefficient	Equation: RCI = a + b (...) a	b	100 RCI	200 RCI	No.	No. of Observations	Correlation Coefficient	Equation: RCI = a + b (...) a	b	100 RCI	200 RCI
[illegible]	[illegible]	-0.[illegible]	21.2[illegible]	[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--
2	[illegible]	[illegible]	[illegible]	[illegible]	--	--	[illegible]	[illegible]	[illegible]	--	--	--	--
[illegible]	1[illegible]	[illegible]	--	--	--	--	[illegible]	1[illegible]	[illegible]	[illegible]	-2.[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--
[illegible]	[illegible]	-0.113	--	--	--	--	[illegible]	[illegible]	--	--	--	--	--
[illegible]	[illegible]	[illegible]	--	--	--	--	[illegible]	0	--	--	--	--	--
[illegible]	[illegible]	-0.[illegible]	--	--	--	--	[illegible]	[illegible]	--	--	--	--	--
10	13	-0.[illegible]**	[illegible]	-[illegible].251	--	--	[illegible]	[illegible]	[illegible]	--	--	--	--
12	1[illegible]	-0.[illegible]**	14.[illegible]	-3.[illegible]	23.5	18.[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--
13	13	-0.[illegible]	--	--	--	--	[illegible]	[illegible]	-0.[illegible]*	12.401	-2.[illegible]	20.0	[illegible]
14	[illegible]	-0.7[illegible]*	21.[illegible]	-[illegible]	2[illegible].1	22.7	[illegible]	[illegible]	-0.[illegible]*	23.[illegible]	-5.[illegible]	23.[illegible]	21.[illegible]
15	[illegible]	--	--	--	--	--	101	[illegible]	-0.[illegible]	--	--	--	--
16	2	--	--	--	--	--	102	[illegible]	-0.[illegible]	--	--	--	--
17	2	--	--	--	--	--	103	[illegible]	-0.[illegible]*	[illegible]	-3.5[illegible]	28.7	2[illegible]
18	1	--	--	--	--	--	105	[illegible]	[illegible]	--	--	--	--
19	[illegible]	--	--	--	--	--	108	[illegible]	-0.701	--	--	--	--
20	21	-0.581**	29.303	-7.684	24.9	22.7	109	[illegible]	-1.000**	25.05[illegible]	-5.941	--	--
21	3	0.57[illegible]	--	--	--	--	110	[illegible]	-0.745	--	--	--	--
22	4	-0.907	--	--	--	--	112	[illegible]	-0.759*	1[illegible].292	-3.459	29.3	24.0
23	0	--	--	--	--	--	114	[illegible]	-0.056	--	--	--	--
24	1	--	--	--	--	--	115	[illegible]	-0.701*	14.700	-3.403	19.4	15.8
25	2	--	--	--	--	--	116	0	--	--	--	--	--
26	14	-0.874**	19.502	-4.318	31.5	26.8	117	4	-0.987**	8.269	-1.013	--	--
27	6	-0.840*	19.338	-4.441	27.6	23.6	119	1	--	--	--	--	--
28	7	-0.857*	17.741	-4.041	2[illegible].8	21.7	120	9	-0.955**	33.293	-8.913	25.0	23.1
29	11	-0.818**	10.237	-1.670	29.1	19.2	123	3	-0.844	--	--	--	--
30	37	-0.749**	13.351	-2.510	32.6	24.7	124	2	--	--	--	--	--
31	39	-0.304	--	--	--	--	125	19	-0.857**	23.130	-5.701	25.8	22.8
32	2	--	--	--	--	--	126	1	--	--	--	--	--
33	4	-0.662	--	--	--	--	127	0	--	--	--	--	--
34	26	-0.729**	20.776	-4.2[illegible]6	43.8	37.3	128	0	--	--	--	--	--
35	13	-0.253	--	--	--	--	129	2	--	--	--	--	--
38	0	--	--	--	--	--	130	5	-0.396*	20.863	-5.012	25.6	22.3
39	17	-0.547*	10.516	-2.026	18.5	13.1	131	12	-0.939**	24.309	-6.060	25.8	23.0
41	0	--	--	--	--	--	132	[illegible]	-0.[illegible]**	1[illegible].[illegible]0	-3.195	46.2	37.2
47	6	-0.582	--	--	--	--	133	11	-0.[illegible]*	20.038	-4.674	27.5	23.7
48	6	-0.609	--	--	--	--	134	11	-0.885**	13.161	-2.280	42.5	31.4
51	4	-0.837	--	--	--	--	135	9	-0.522	--	--	--	--
58	9	-0.913**	13.116	-2.387	35.3	26.4	136	12	-0.938**	12.799	-2.393	30.7	23.0
60	16	-0.323	--	--	--	--	150	0	--	--	--	--	--
61	21	-0.373	--	--	--	--	151	0	--	--	--	--	--
62	0	--	--	--	--	--	152	2	--	--	--	--	--
67	12	-0.653*	22.594	-5.026	35.8	31.2	153	6	-0.941**	24.940	-6.514	22.7	20.4
71	10	-0.909**	23.918	-6.204	22.5	20.1	155	8	-0.824*	32.101	-7.961	31.6	29.0
72	8	-0.804*	30.334	-8.240	22.7	20.9	156	7	-0.934**	18.377	-4.035	30.4	25.[illegible]
74	9	-0.553	--	--	--	--							
75	0	--	--	--	--	--							
76	4	-0.049	--	--	--	--							
79	2	--	--	--	--	--							
81	6	-0.237	--	--	--	--							

* Significant at 5% level.
** Significant at 1% level.

[illegible]	7	[illegible]	--	--	[illegible]†	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]†	[illegible]
4	1	[illegible]	--	--	[illegible]†	[illegible]
6	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]†	[illegible]
7	4	[illegible]	--	--	[illegible]44†	0.0[illegible]
[illegible]	[illegible]	[illegible]	--	--	[illegible]80†	0.02
[illegible]	[illegible]	-0.30[illegible]	--	--	[illegible]51	0.10
10	13	-0.4[illegible]7	--	--	[illegible]†	0.04
12	19	-0.[illegible]70*	[illegible]	-1.[illegible]0	0.[illegible]4†	0.0[illegible]
13	13	[illegible].273	--	--	1.06†	0.03
14	[illegible]	-0.743*	9.43[illegible]	-2.724	0.[illegible]†	0.04
15	0	--	--	--	--	--
16	2	--	--	--	0.77	0.12
17	2	--	--	--	0.[illegible]	0.[illegible]4
18	1	--	--	--	0.77	--
19	0	--	--	--	--	--
20	21	-0.284	--	--	0.47†	0.02
21	3	0.[illegible]	--	--	0.42	0.04
22	4	-0.724	--	--	[illegible]	0.2[illegible]
23	0	--	--	--	--	--
24	1	--	--	--	0.74	--
25	2	--	--	--	0.7[illegible]	0.07
26	14	-0.[illegible]1	--	--	0.75†	0.02
27	6	-0.710	--	--	0.[illegible]3†	0.06
28	7	-0.71[illegible]	--	--	0.94†	0.03
29	[illegible]	0.3[illegible]5	--	--	0.81†	0.03
30	3[illegible]	-0.141	--	--	0.77†	0.02
31	39	-0.203	--	--	[illegible]	0.02
32	2	--	--	--	0.68	0.0[illegible]
33	4	-0.408	--	--	0.73	0.09
34	26	0.261	--	--	1.22†	0.06
35	13	-0.210	--	--	0.73	0.0[illegible]
38	0	--	--	--	--	--
39	17	-0.359	--	--	0.61†	0.01
41	0	--	--	--	--	--
47	6	-0.267	--	--	0.75†	0.04
48	6	0.[illegible]*	-3.95[illegible]	1.171	0.82†	0.03
51	4	-0.[illegible]*	17.171	-5.67[illegible]	2.89	0.5†
58	9	0.370	--	--	1.08†	0.02
60	16	-0.283	--	--	0.64†	0.02
61	21	-0.449*	9.906	-2.252	0.70†	0.02
62	0	--	--	--	--	--
67	12	-0.622*	12.393	-3.590	0.39[illegible]	0.04
71	10	-0.842**	13.616	-4.576	0.39†	0.05
72	8	-0.527	--	--	0.16†	0.01
74	6	-0.051	--	--	0.40†	0.01
75	0	--	--	--	--	--
76	4	0.595	--	--	0.71	0.01
79	2	--	--	--	0.87	0.01
81	6	-0.450	--	--	0.71†	0.04

[illegible]	1	[illegible]	--	--	[illegible]†	[illegible]1
[illegible]	[illegible]	[illegible]	--	--	[illegible]2	[illegible]
[illegible]	[illegible]	[illegible]	--	--	[illegible]†	0.01
[illegible]	[illegible]	[illegible].11[illegible]	--	--	[illegible]†	0.04
[illegible]		--	--	--	--	--
[illegible]	[illegible]	--	--	--	--	--
[illegible]	[illegible]	--	--	--	--	--
[illegible]	[illegible]	[illegible]1	--	--	[illegible]41†	[illegible]02
[illegible]		-0.112	--	--	[illegible]†	0.04
[illegible]	11	[illegible].117	--	--	[illegible]†	0.01
[illegible]	12	-0.4[illegible]7	--	--	[illegible]21†	[illegible]2
101	[illegible]	-0.28[illegible]	--	--	[illegible]†	0.02
102	[illegible]	-0.3[illegible]	--	--	[illegible]†	[illegible]
103	[illegible]	-0.[illegible]	--	--	[illegible]	[illegible]
10[illegible]		-0.[illegible]82	--	--	0.78†	[illegible]
10[illegible]	[illegible]	-0.[illegible]	--	--	[illegible]†	[illegible]
10[illegible]		-1.[illegible]**	[illegible]	-1.[illegible]1	0.82	[illegible].03
110	[illegible]	-0.[illegible]3*	7.037	-2.133	0.72†	0.03
112	7	[illegible]**	[illegible].755	-1.7[illegible]	0.73†	0.05
114	[illegible]	-0.0[illegible]	--	--	[illegible]†	[illegible]4
115	[illegible]	-0.33[illegible]	--	--	0.5[illegible]†	0.02
116	0	--	--	--	--	--
117	4	0.511	--	--	1.32	0.10
119	1	--	--	--	[illegible]	--
120	[illegible]	-0.[illegible]**	1[illegible]	-[illegible]	[illegible]†	[illegible]
123	[illegible]	-0.721	--	--	0.[illegible]	0.0[illegible]
124	2	--	--	--	0.29	0.03
125	10	-0.4[illegible]3*	10.311	-3.417	0.[illegible]21	0.04
126	1	--	--	--	0.9[illegible]	--
127	0	--	--	--	--	--
128	0	--	--	--	--	--
129	2	--	--	--	0.[illegible]1	[illegible]
130	5	-0.545	--	--	0.53†	0.04
131	12	-0.750**	7.500	-2.425	0.72†	0.03
132	6	-0.191	--	--	1.01†	0.02
133	11	0.351	--	--	0.7[illegible]†	0.02
134	11	0.217	--	--	1.04†	0.05
135	[illegible]	0.027	--	--	1.02	[illegible]
136	12	-0.461	--	--	0.83†	0.02
150	0	--	--	--	--	--
151	0	--	--	--	--	--
152	2	--	--	--	0.[illegible]	0.05
153	[illegible]	-0.[illegible]42**	12.718	-4.125	0.50	0.0[illegible]
155	8	-0.[illegible]94*	20.[illegible]18	-6.197	0.57	0.11
156	7	-0.890**	7.981	-2.414	[illegible]	0.39

* Significant at 5% level.
** Significant at 1% level.
† Value used for establishing mean RI relations.



TYPICAL CONE INDEX —
SOIL MOISTURE PLOTS

PLATE I

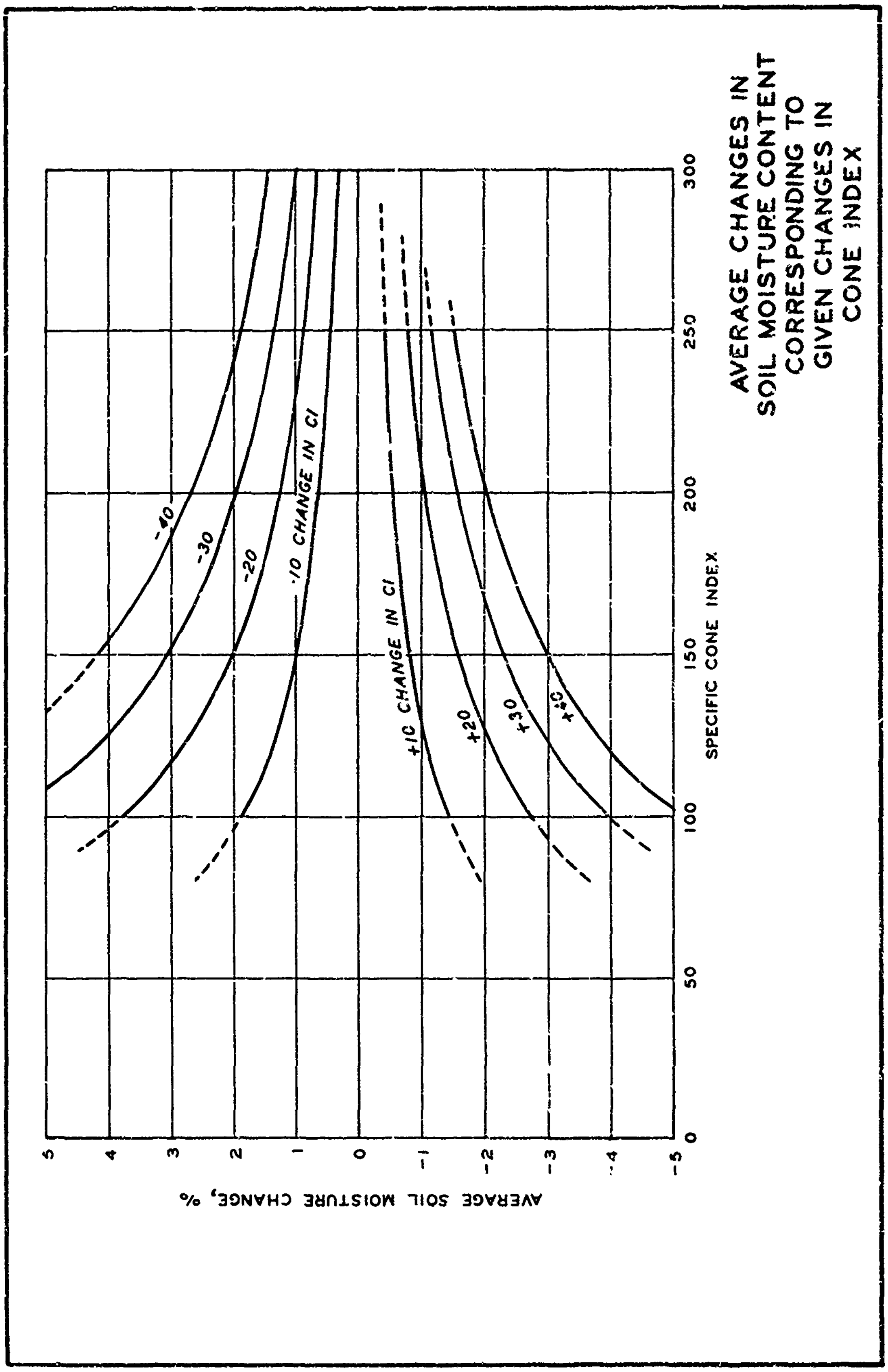
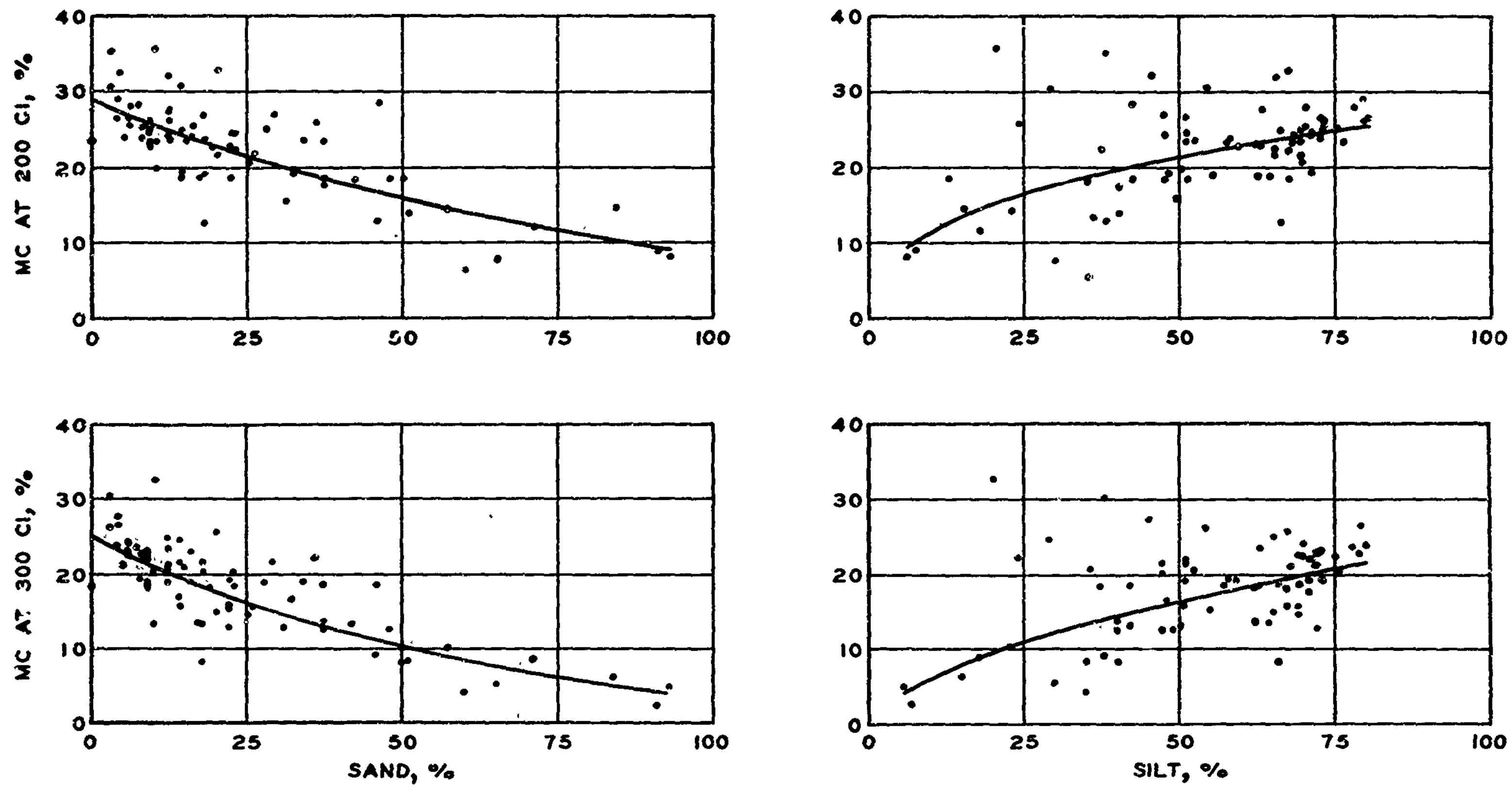
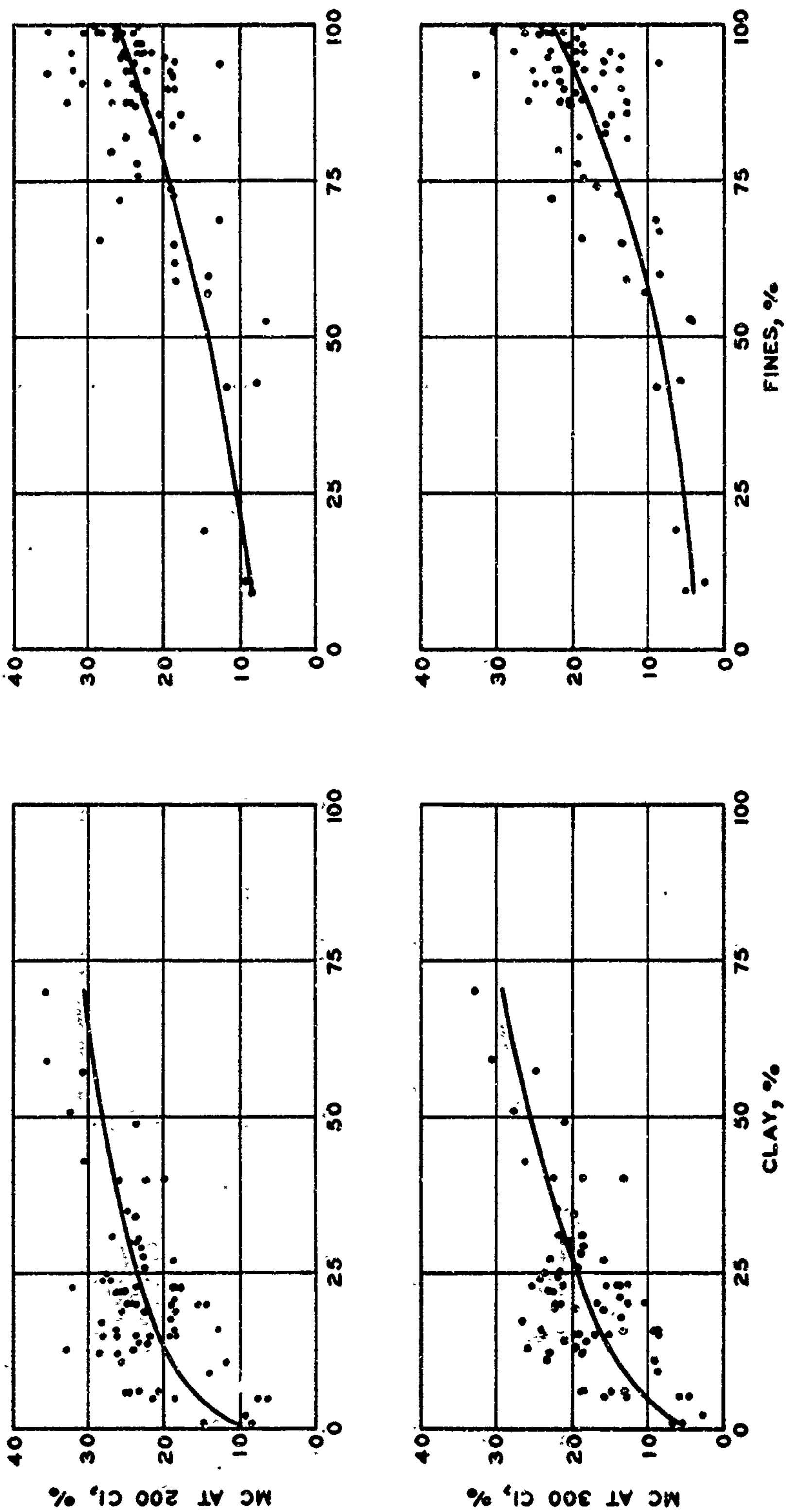

AVERAGE CHANGES IN SOIL MOISTURE CONTENT CORRESPONDING TO GIVEN CHANGES IN CONE INDEX
SPECIFIC CONE INDEX
AVERAGE SOIL MOISTURE CHANGE, %
-10 CHANGE IN CI
-20
-30
-40
+10 CHANGE IN CI
+20
+30
+40
0
50
100
150
200
250
300
5
4
3
2
1
0
-1
-2
-3
-4
-5

PLATE 2



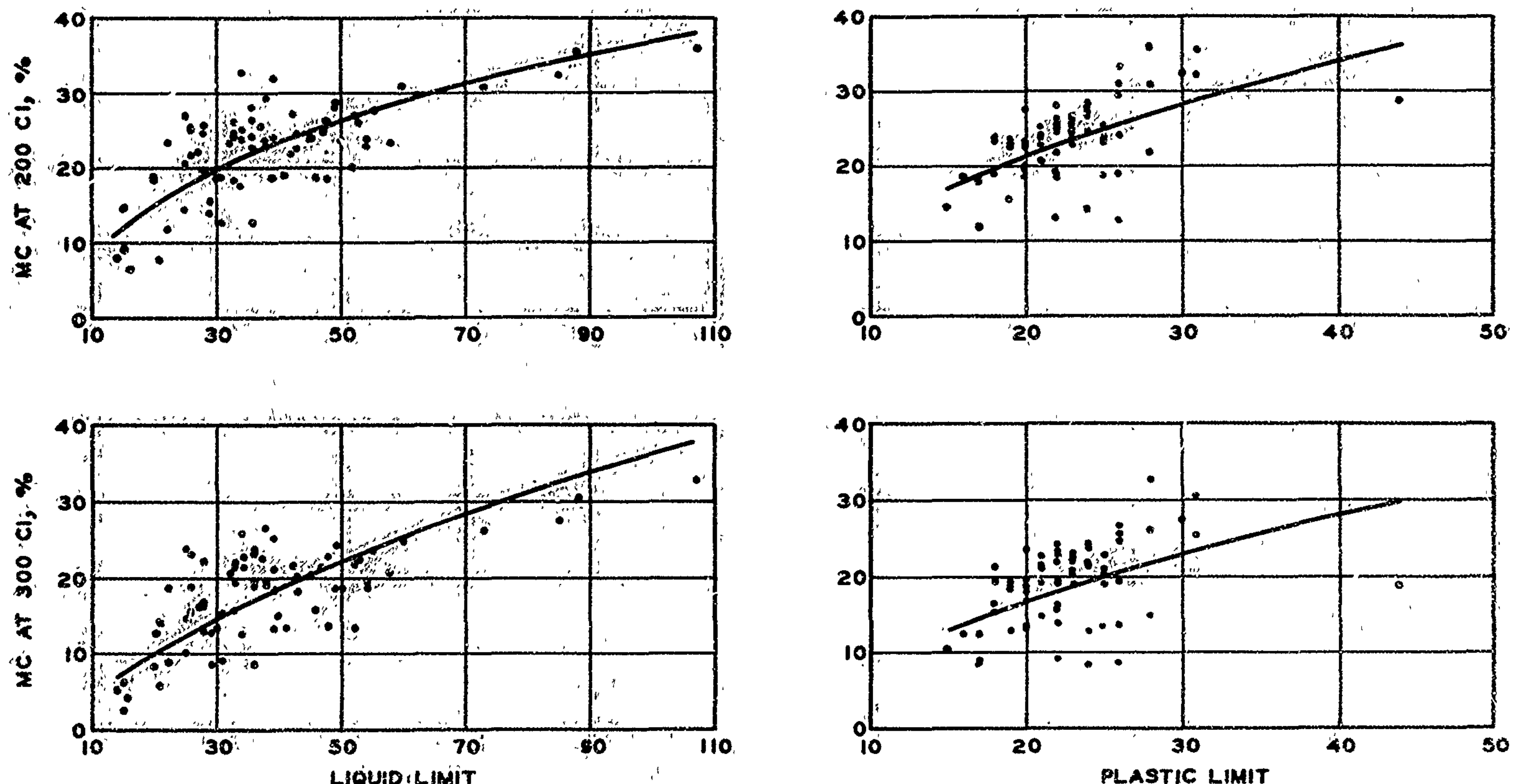
RELATION OF CI–MC COEFFICIENTS TO SAND AND SILT CONTENTS

PLATE 3

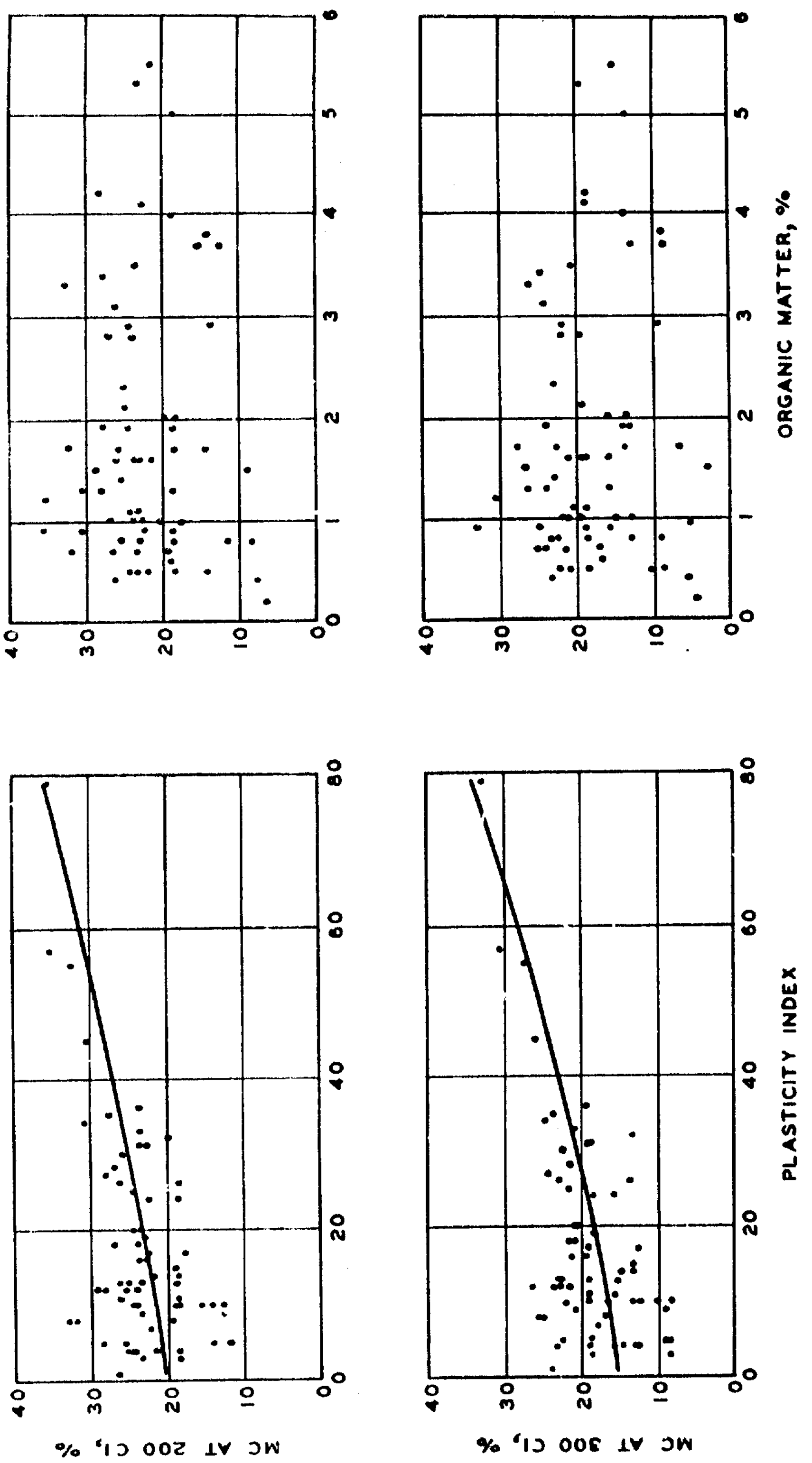


RELATION OF CI–MC
COEFFICIENTS TO
CLAY AND FINES CONTENTS

PLATE 4

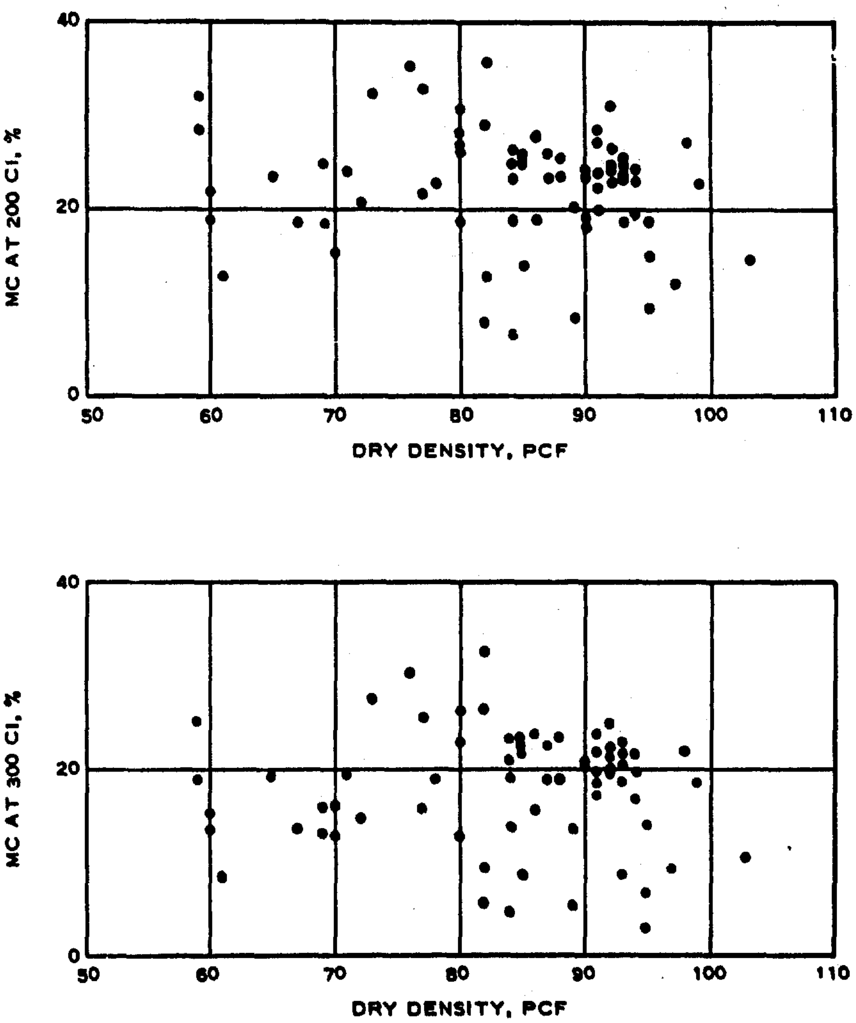


RELATION OF CI–MC COEFFICIENTS TO LIQUID AND PLASTIC LIMITS

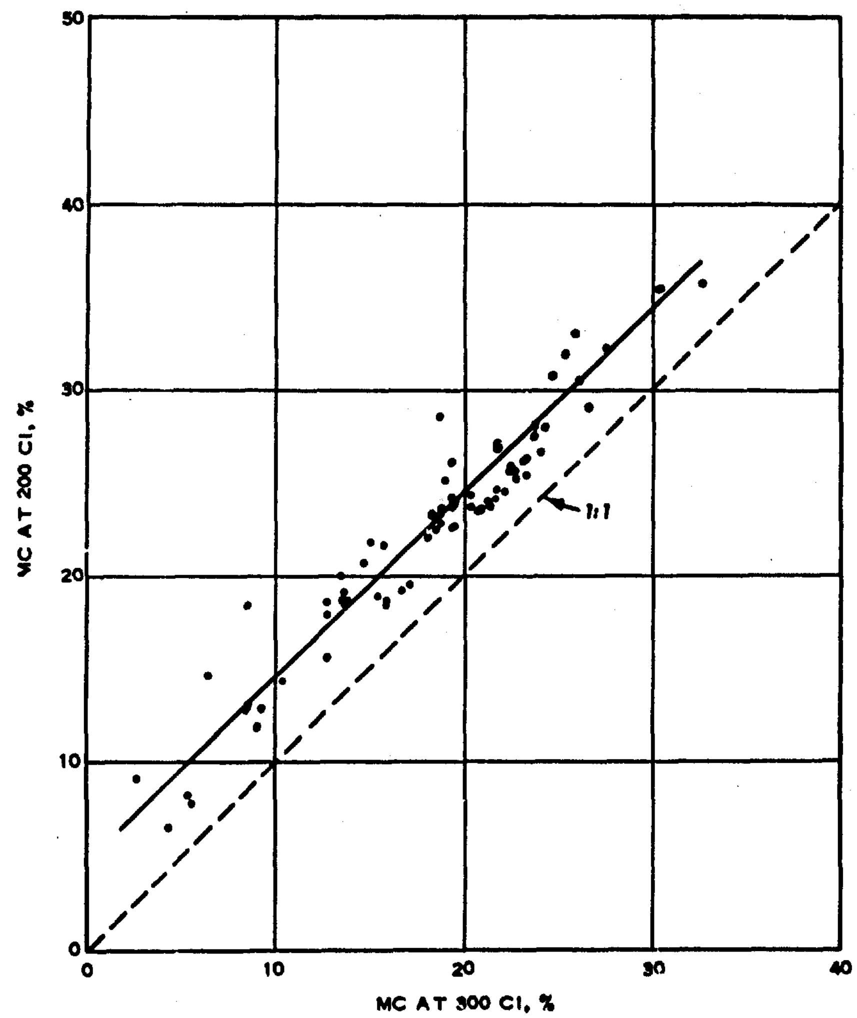


RELATION OF CI–MC COEFFICIENTS TO PLASTICITY INDEX AND ORGANIC MATTER CONTENT

PLATE 6



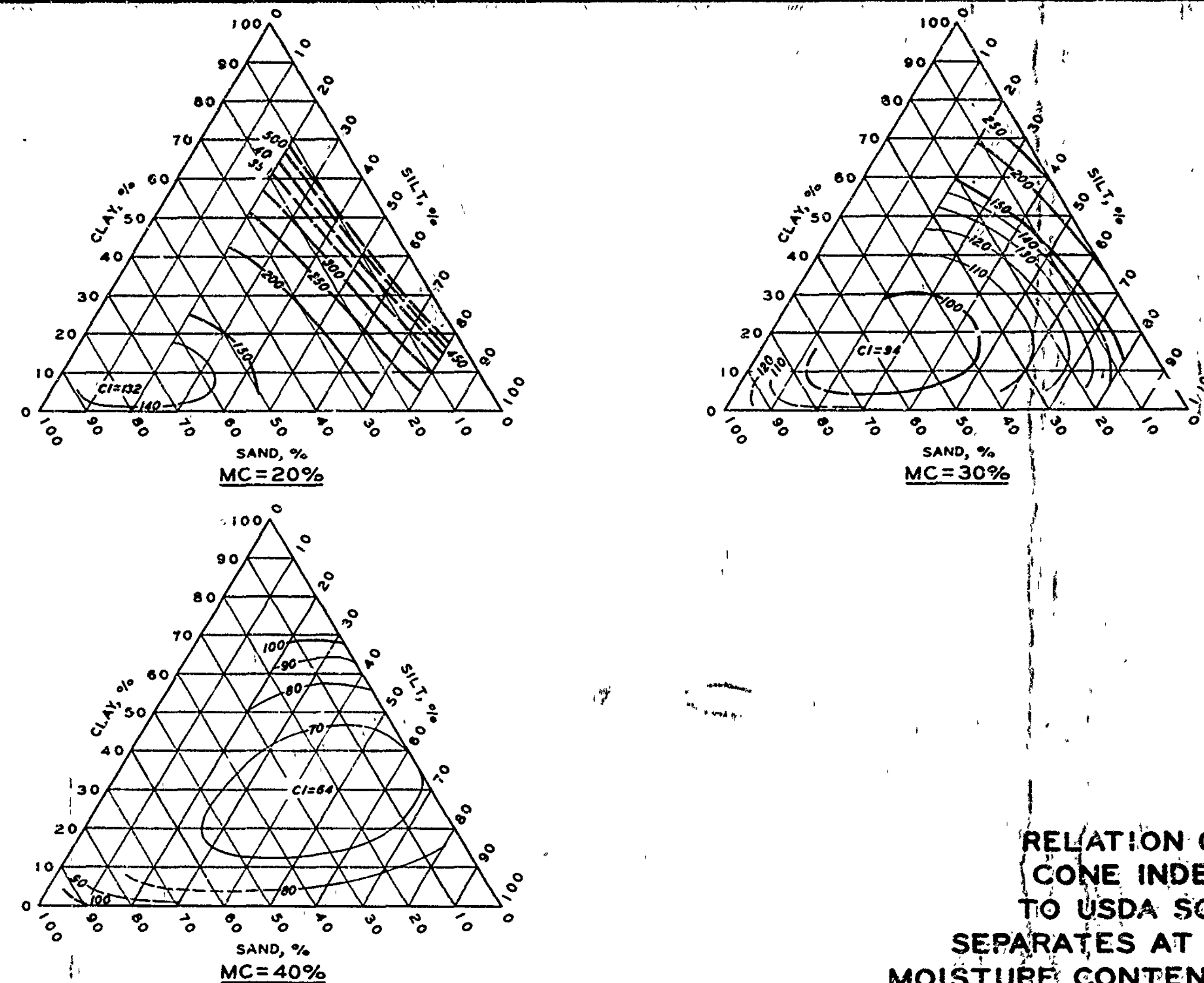
RELATION OF CI-MC COEFFICIENTS
TO DRY DENSITY



NOTE: MC AT 200 CI = 4.783 + 0.982 MC AT 300 CI.
CORRELATION COEFFICIENT = 0.953.

RELATION BETWEEN MC AT 200 CI
AND MC AT 300 CI

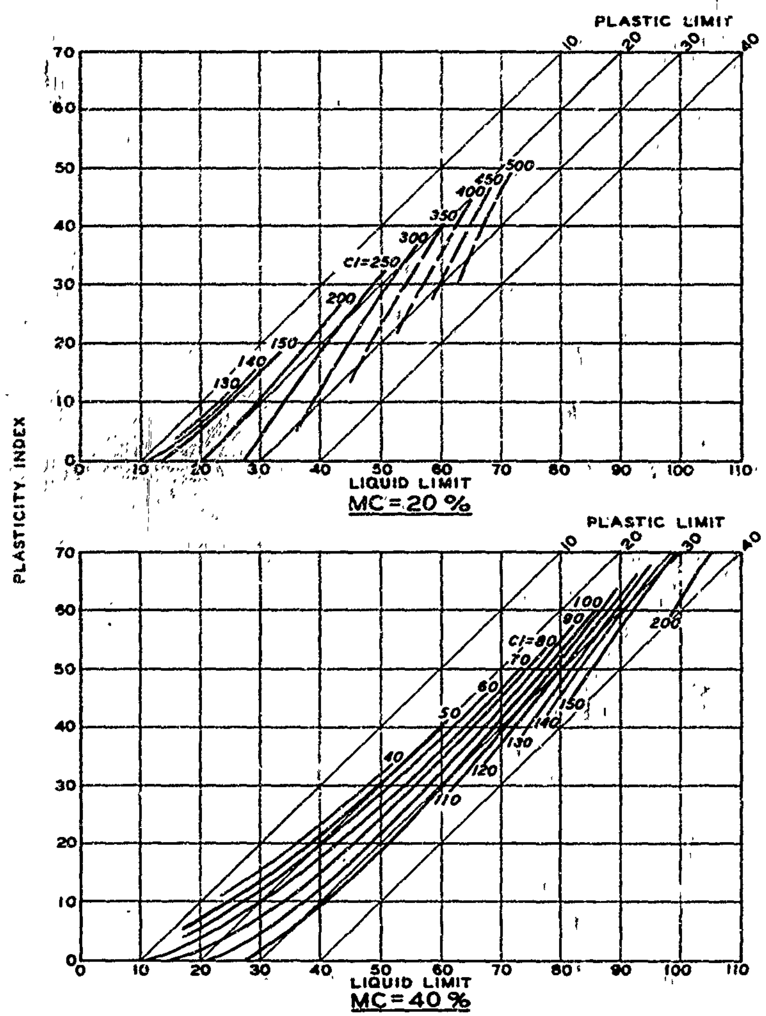
PLATE 8



RELATION OF
CONE INDEX
TO USDA SOIL
SEPARATES AT THREE
MOISTURE CONTENT LEVELS

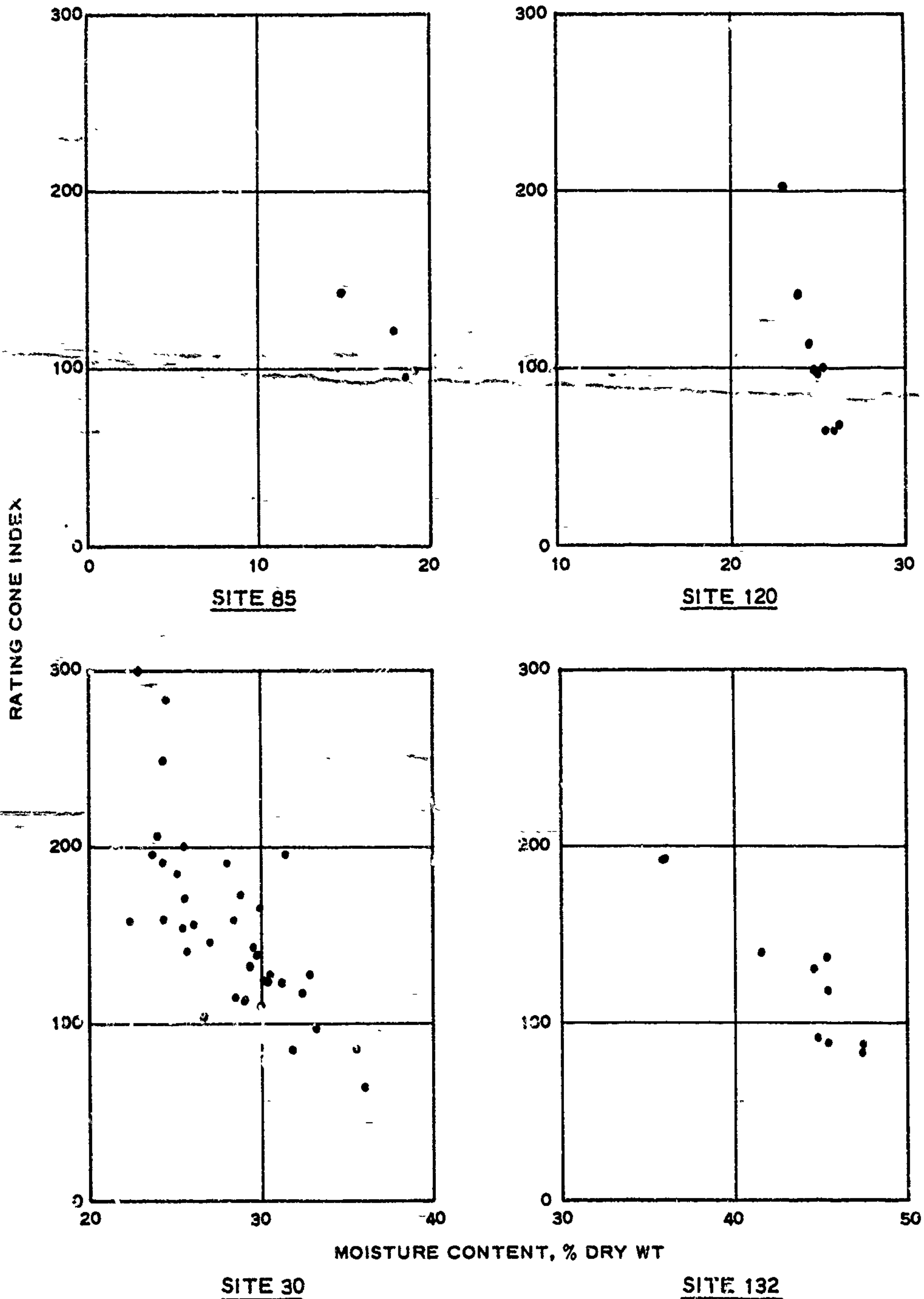
PLATE 9

PLATE 10



RELATION OF CONE INDEX TO ATTERBERG LIMITS

THREE MOISTURE CONTENT LEVELS



TYPICAL RATING CONE INDEX—
SOIL MOISTURE PLOTS

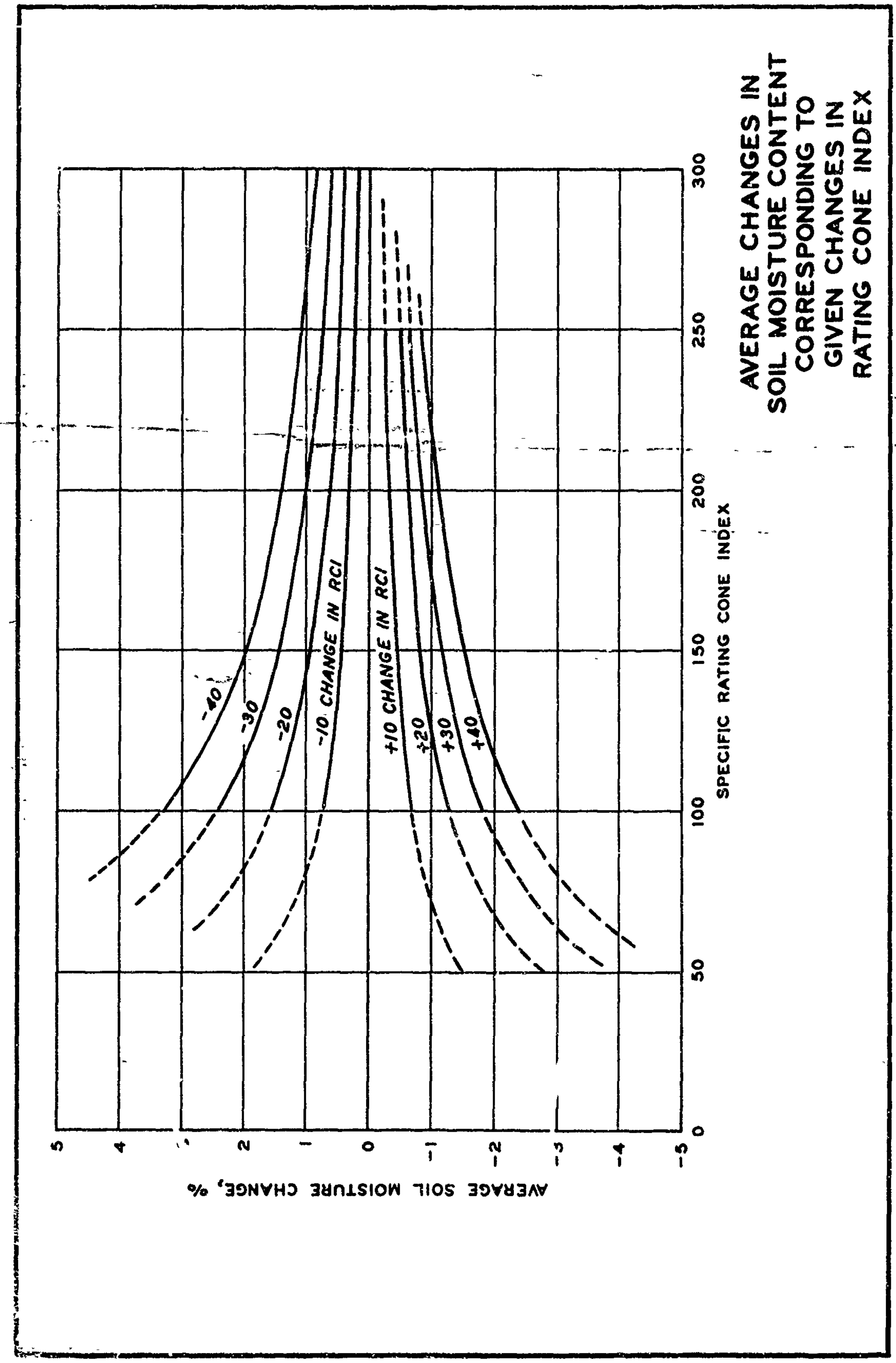
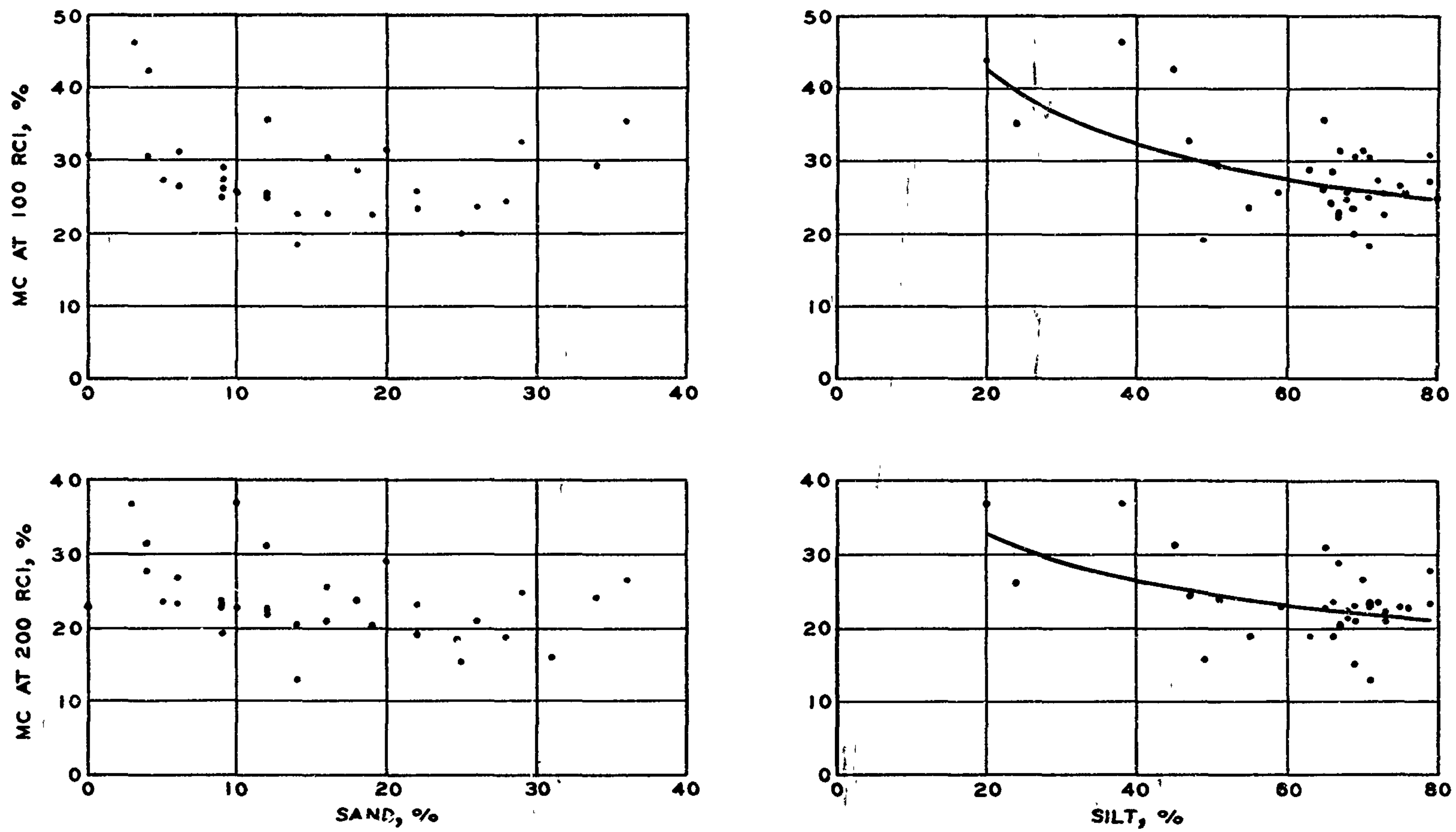

AVERAGE CHANGES IN
SOIL MOISTURE CONTENT
CORRESPONDING TO
GIVEN CHANGES IN
RATING CONE INDEX
SPECIFIC RATING CONE INDEX
AVERAGE SOIL MOISTURE CHANGE, %
-10 CHANGE IN RCI
+10 CHANGE IN RCI
-40
-30
-20
+20
+30
+40
0
50
100
150
200
250
300
5
4
2
1
-1
-2
-3
-4
-5

PLATE 12



RELATION OF RCI–MC
COEFFICIENTS TO
SAND AND SILT CONTENTS

PLATE 13

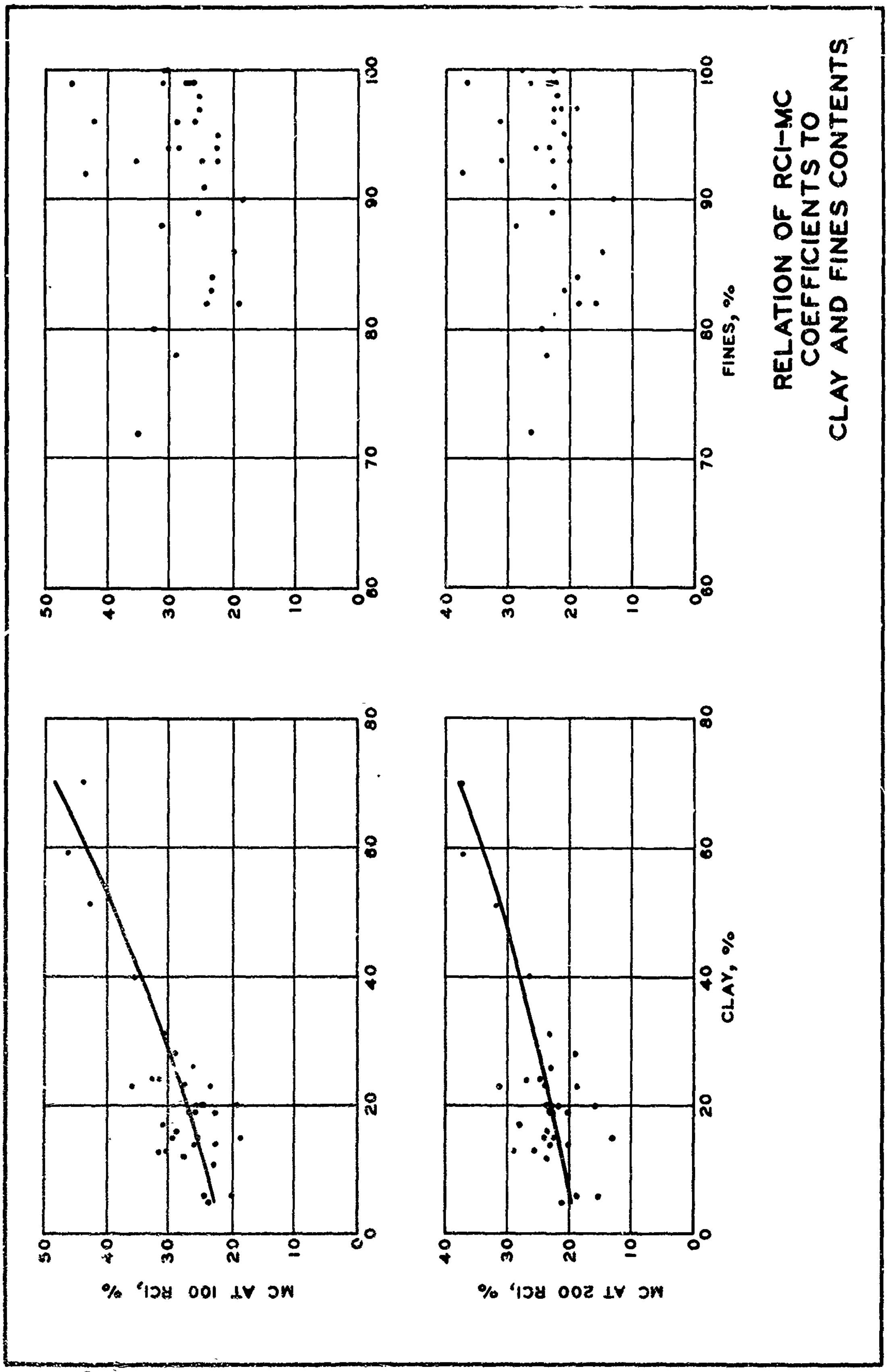
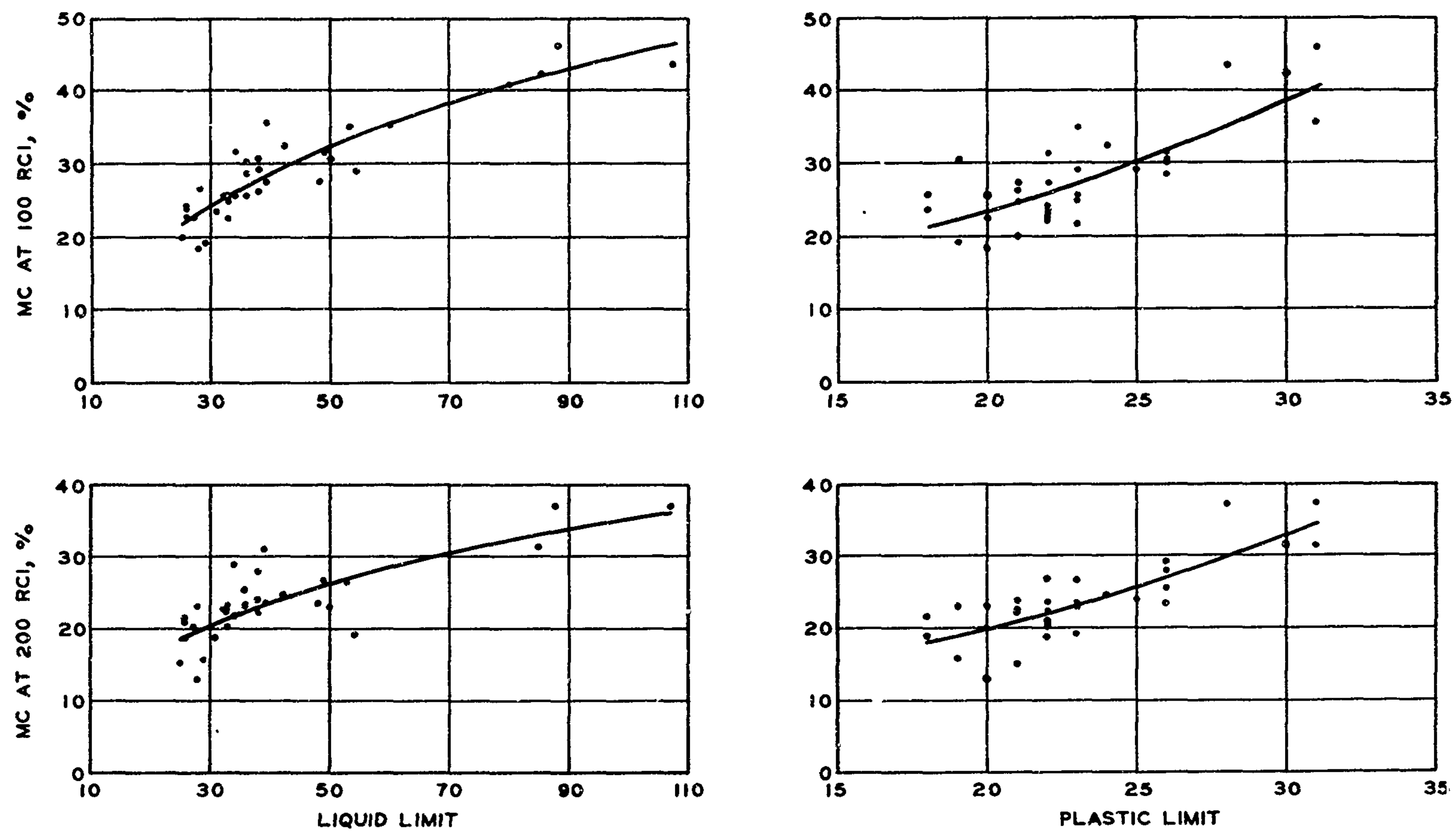
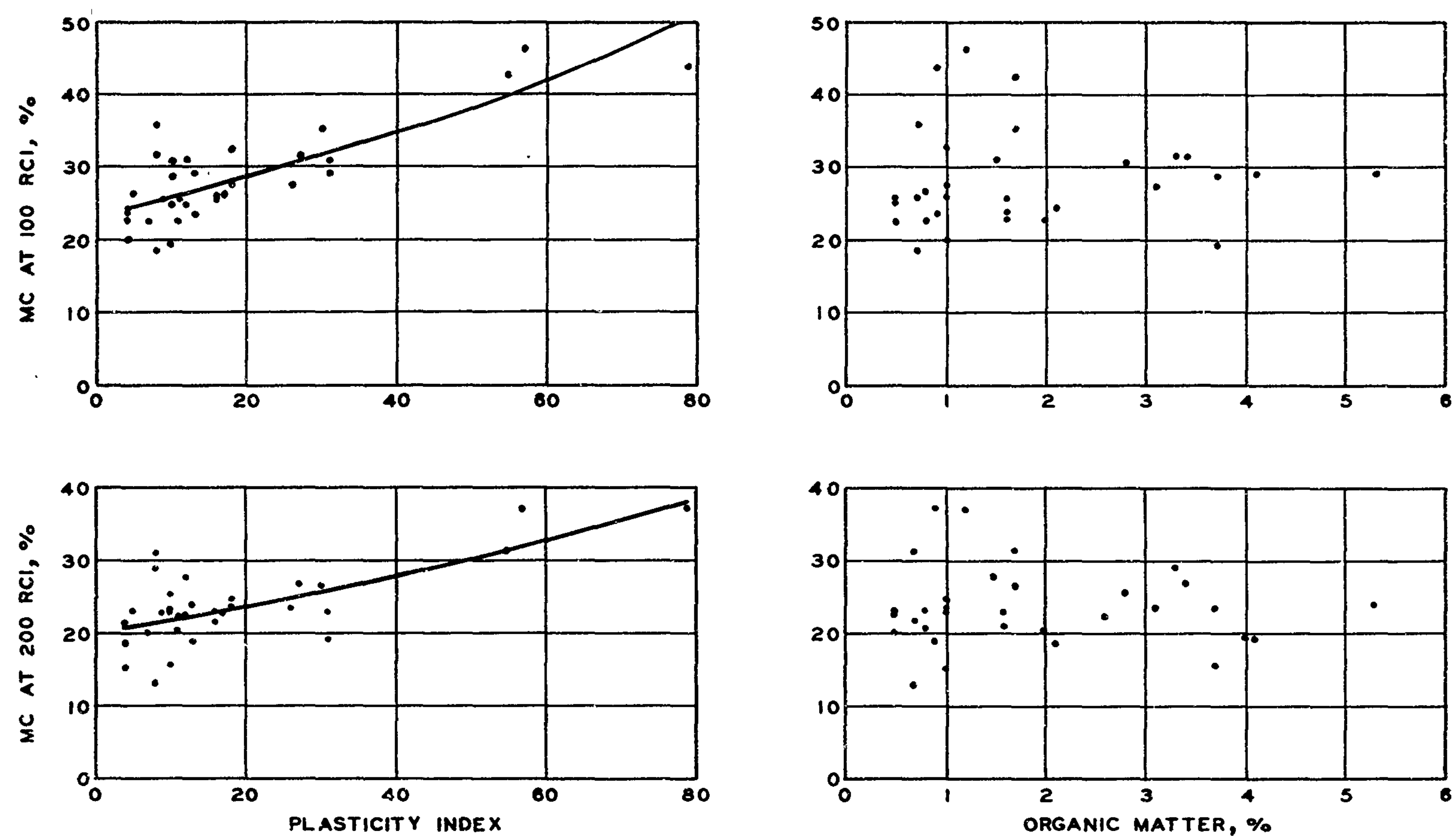

RELATION OF RCI–MC
COEFFICIENTS TO
CLAY AND FINES CONTENTS
MC AT 100 RCI, %
MC AT 200 RCI, %
CLAY, %
FINES, %

PLATE 14



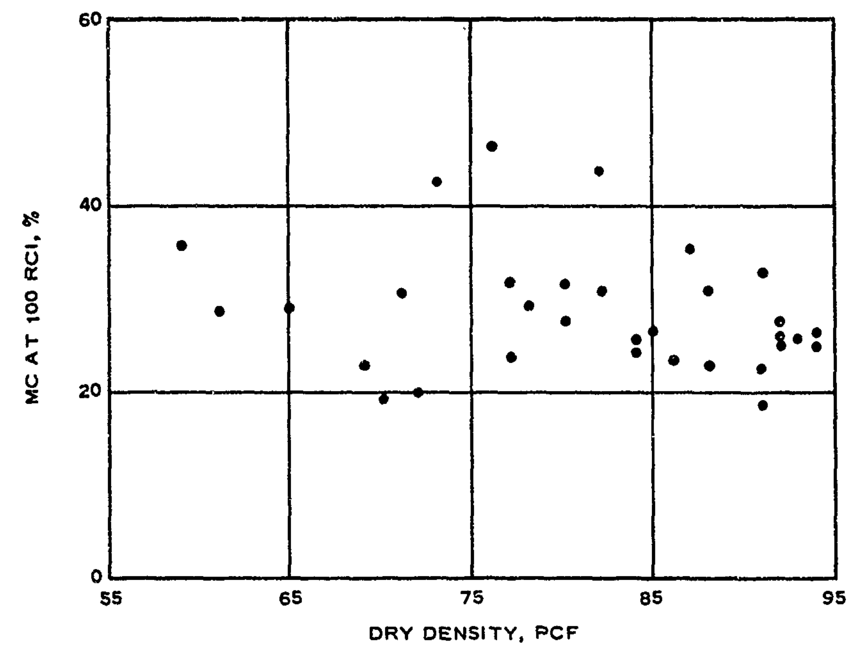
RELATION OF RCI-MC COEFFICIENTS TO LIQUID AND PLASTIC LIMITS

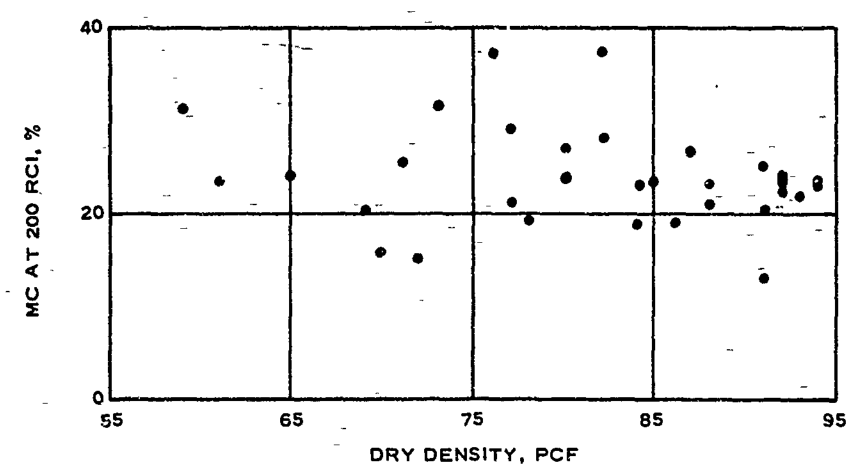
PLATE 15



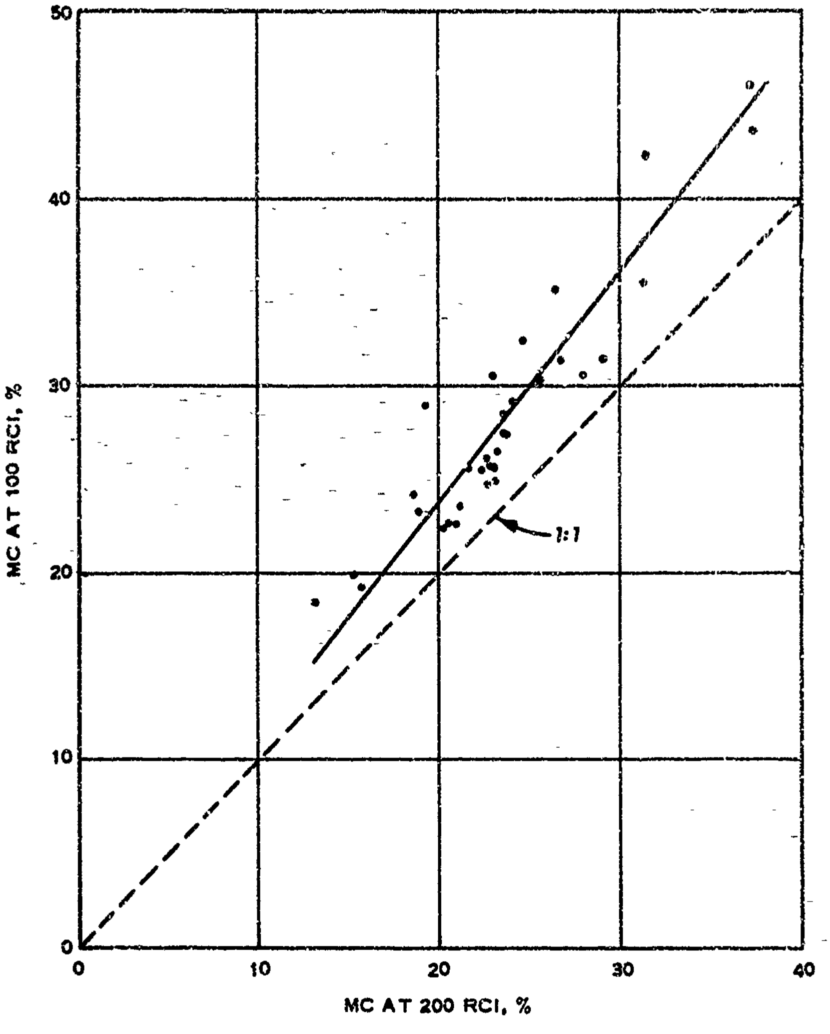
RELATION OF RCI–MC COEFFICIENTS TO PLASTICITY INDEX AND ORGANIC MATTER CONTENT

PLATE 16



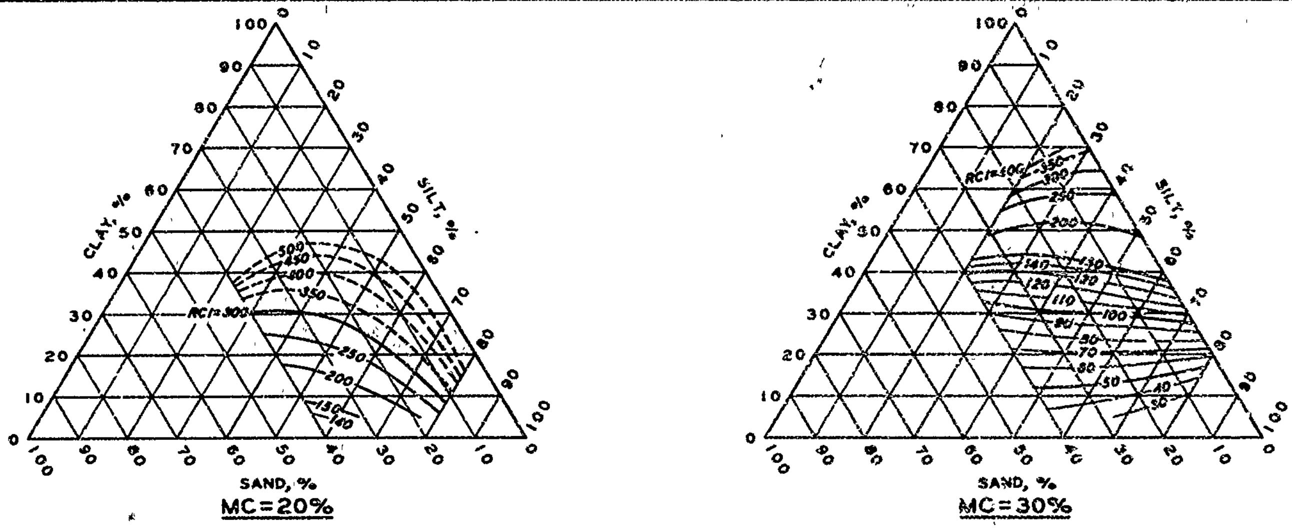


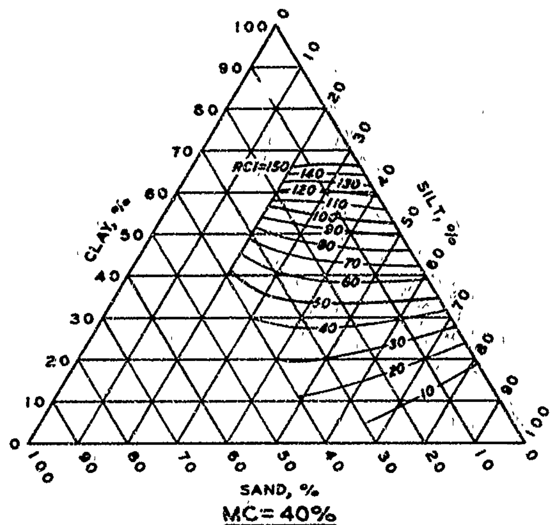
RELATION OF RCI-MC COEFFICIENTS
TO DRY DENSITY



NOTE: MC AT 100 RCI = −0.745 + 1.231 MC AT 200 RCI.
CORRELATION COEFFICIENT = 0.938.

RELATION BETWEEN MC AT 100 RCI
AND MC AT 200 RCI





RELATION OF
RATING CONE INDEX
TO USDA SOIL
SEPARATES AT THREE
MOISTURE CONTENT LEVELS

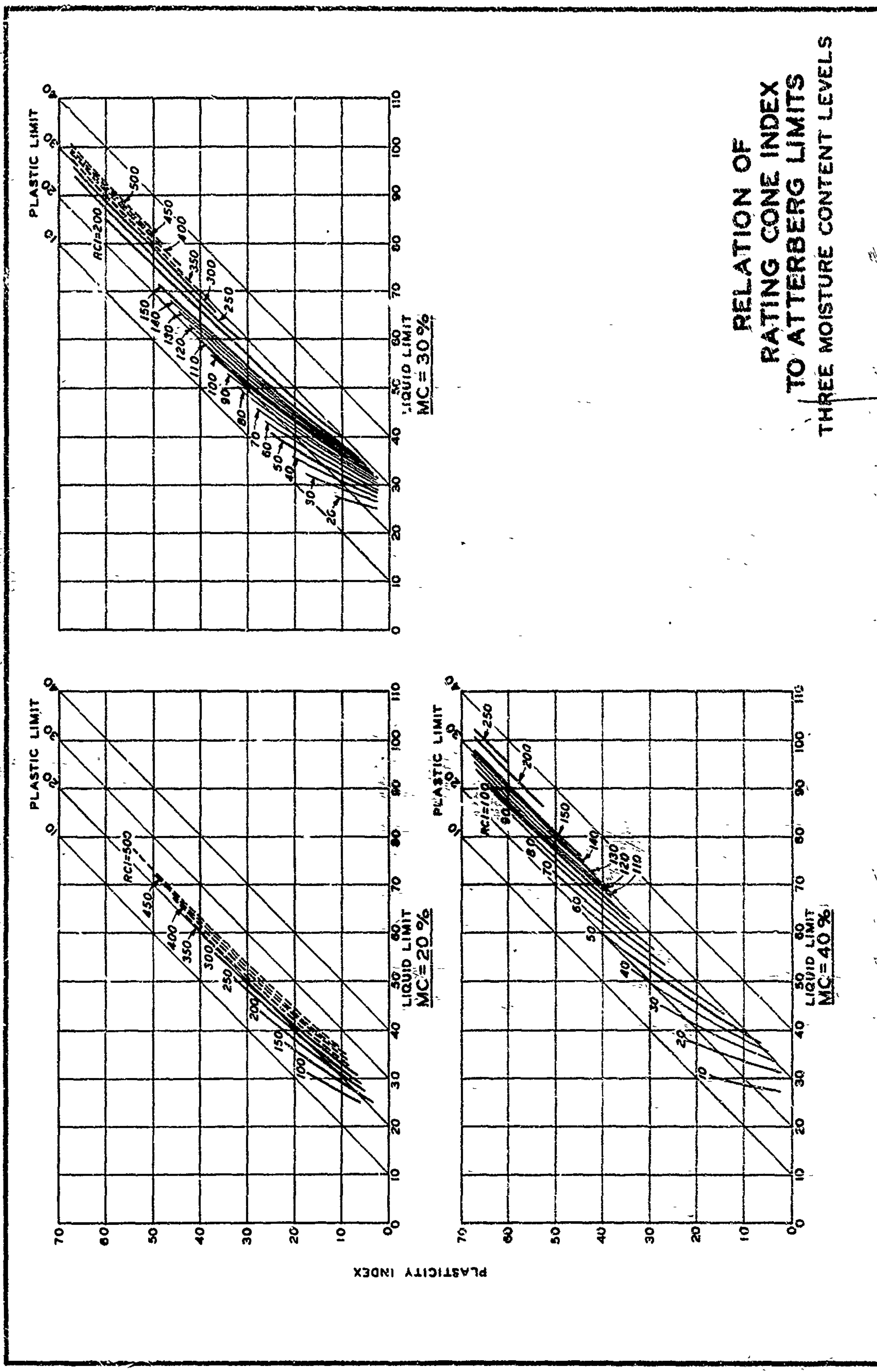
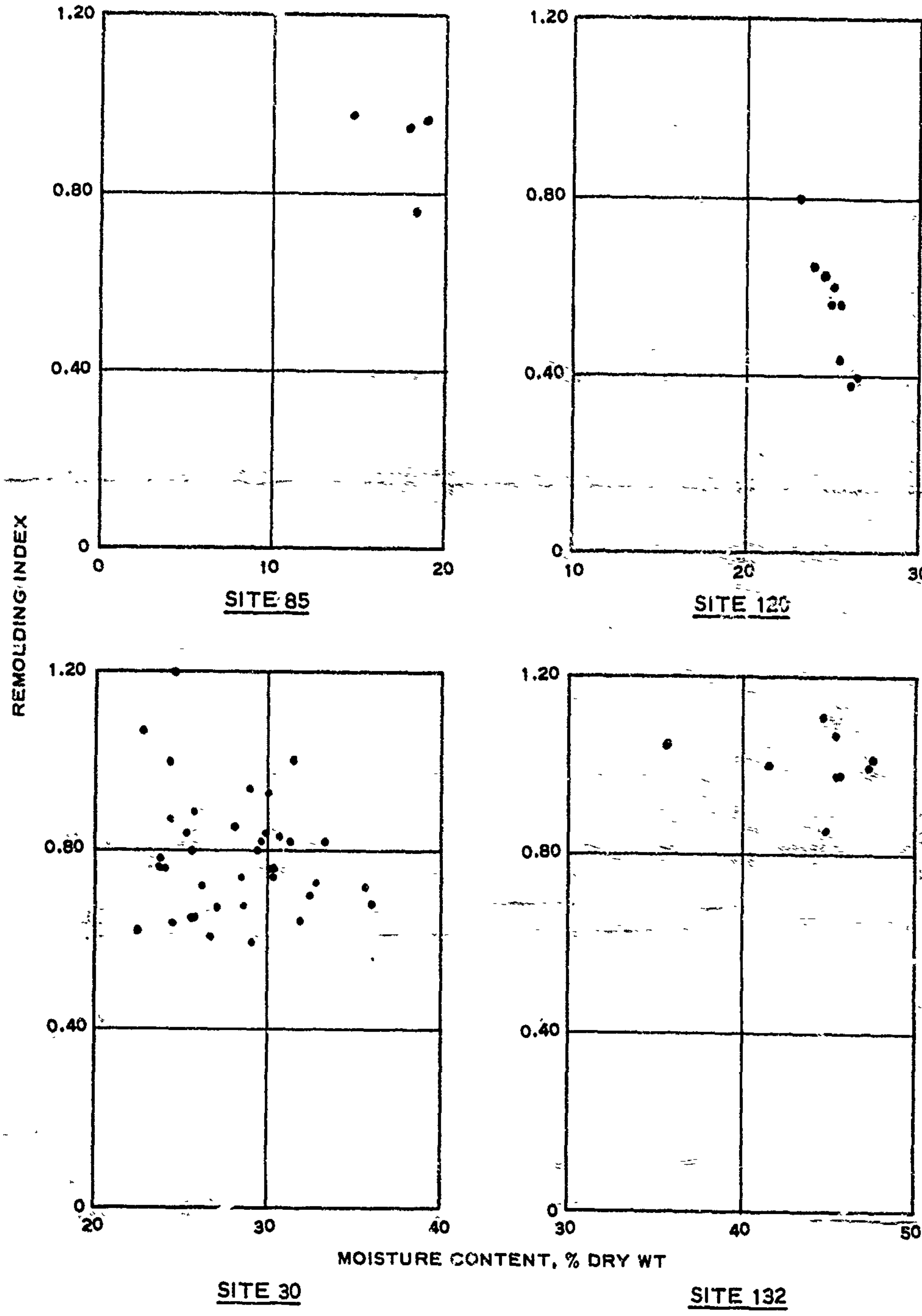

RELATION OF
RATING CONE INDEX
TO ATTERBERG LIMITS
THREE MOISTURE CONTENT LEVELS
PLASTIC LIMIT
LIQUID LIMIT
MC = 30 %
MC = 20 %
MC = 40 %
PLASTICITY INDEX

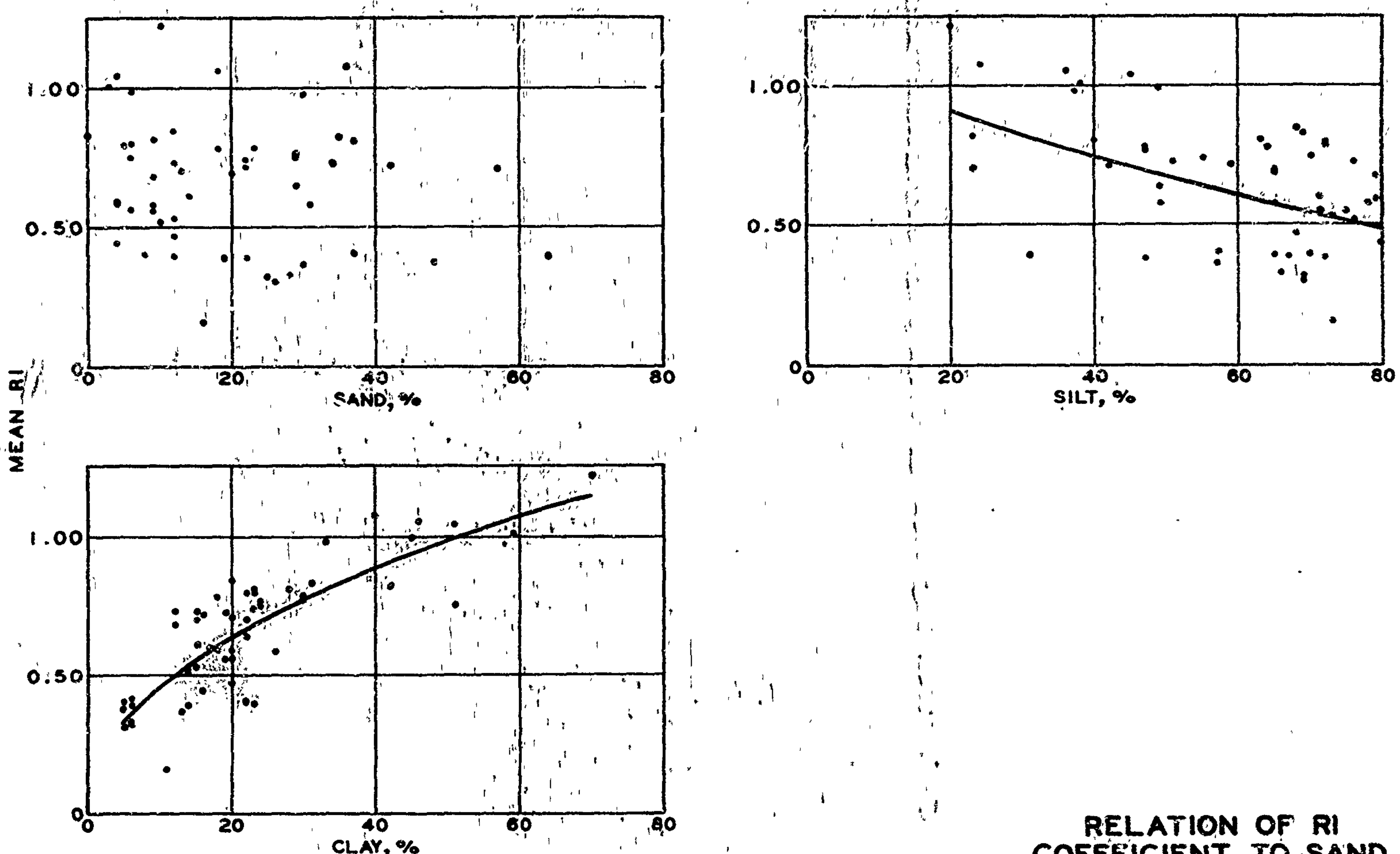
PLATE 20



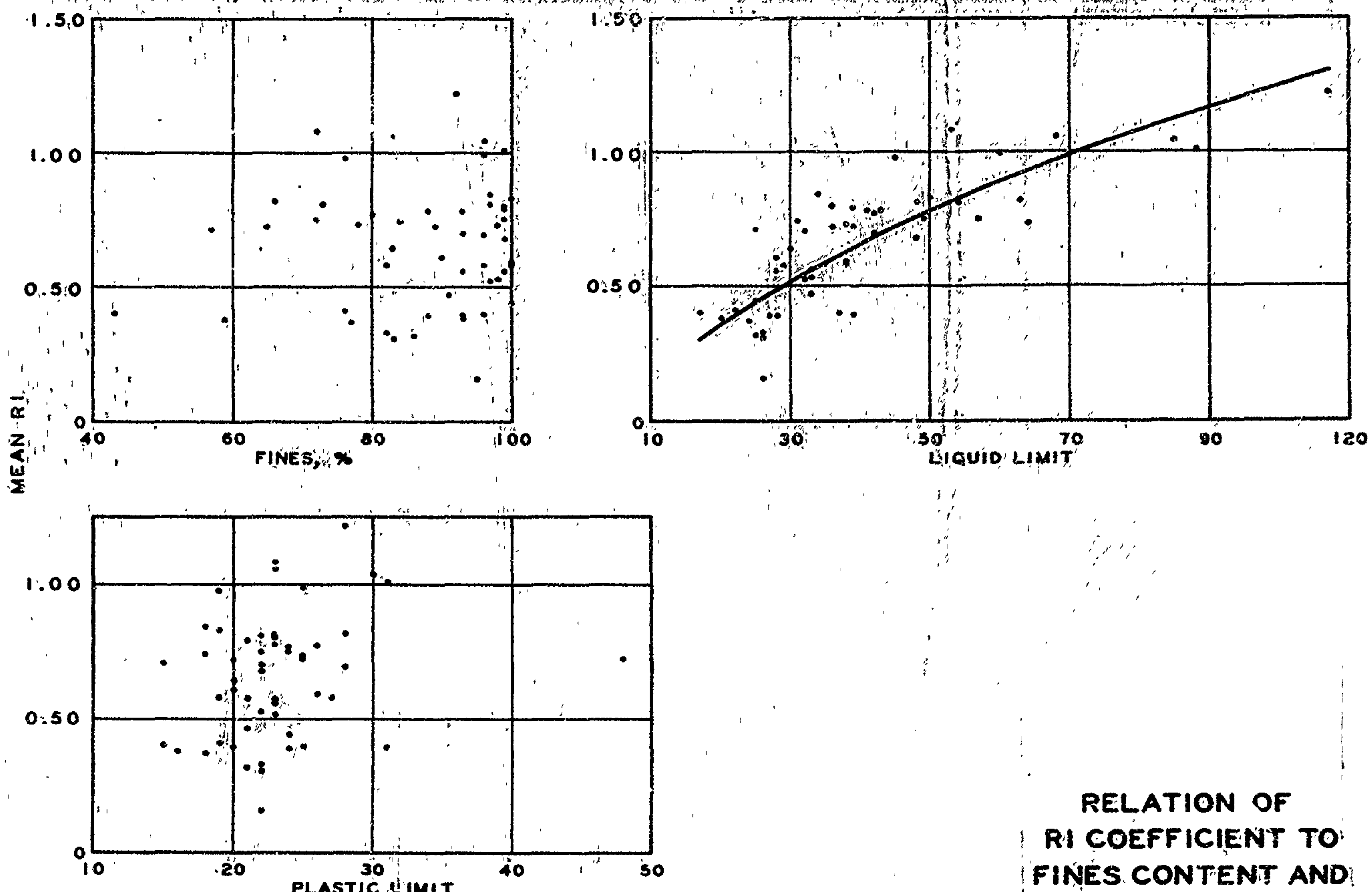
TYPICAL REMOLDING INDEX—
SOIL MOISTURE PLOTS

PLATE 21

PLATE 22



RELATION OF RI
COEFFICIENT TO SAND,
SILT, AND CLAY CONTENTS



RELATION OF
RI COEFFICIENT TO
FINES CONTENT AND
LIQUID AND PLASTIC LIMITS

PLATE 23

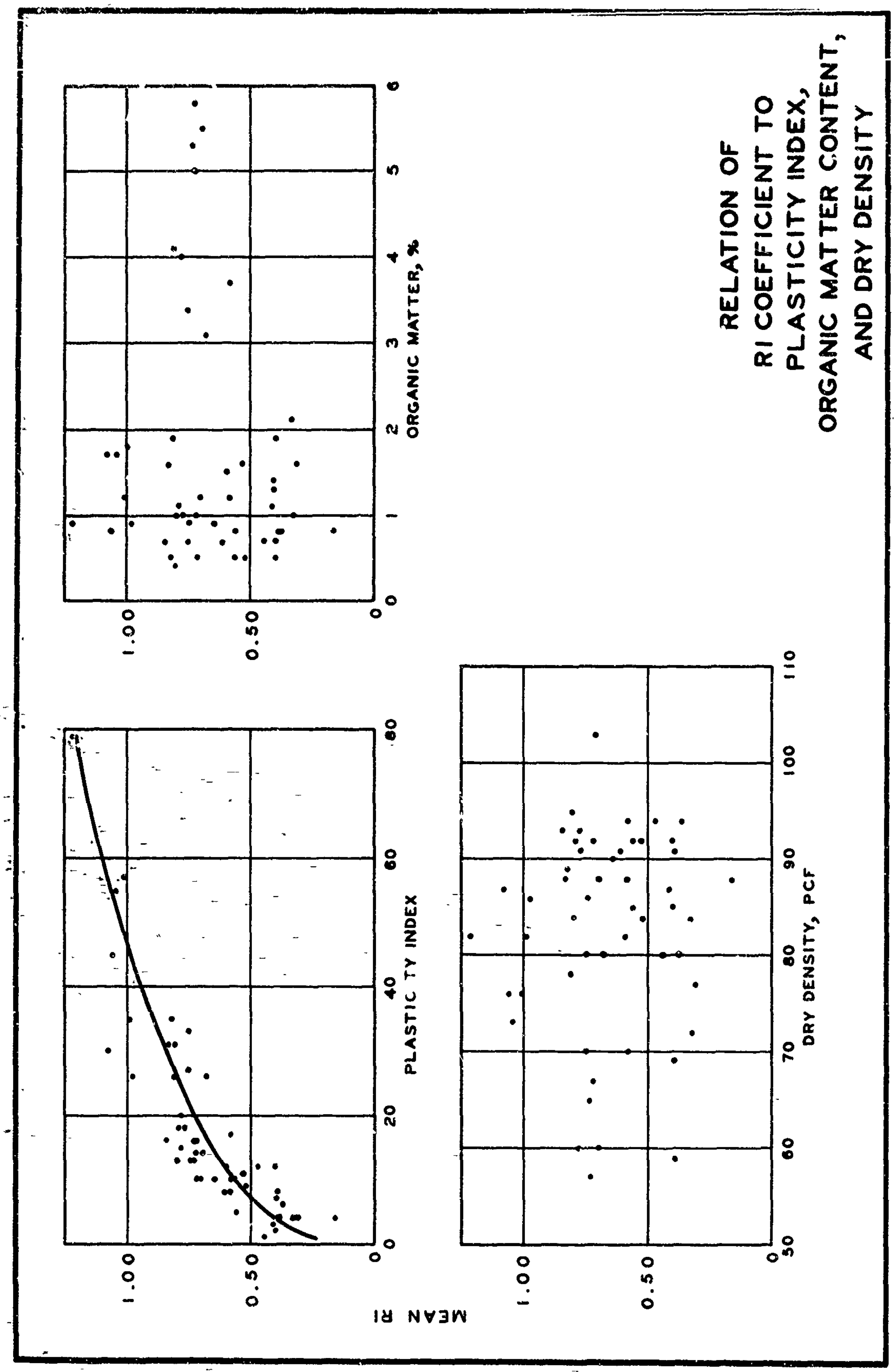
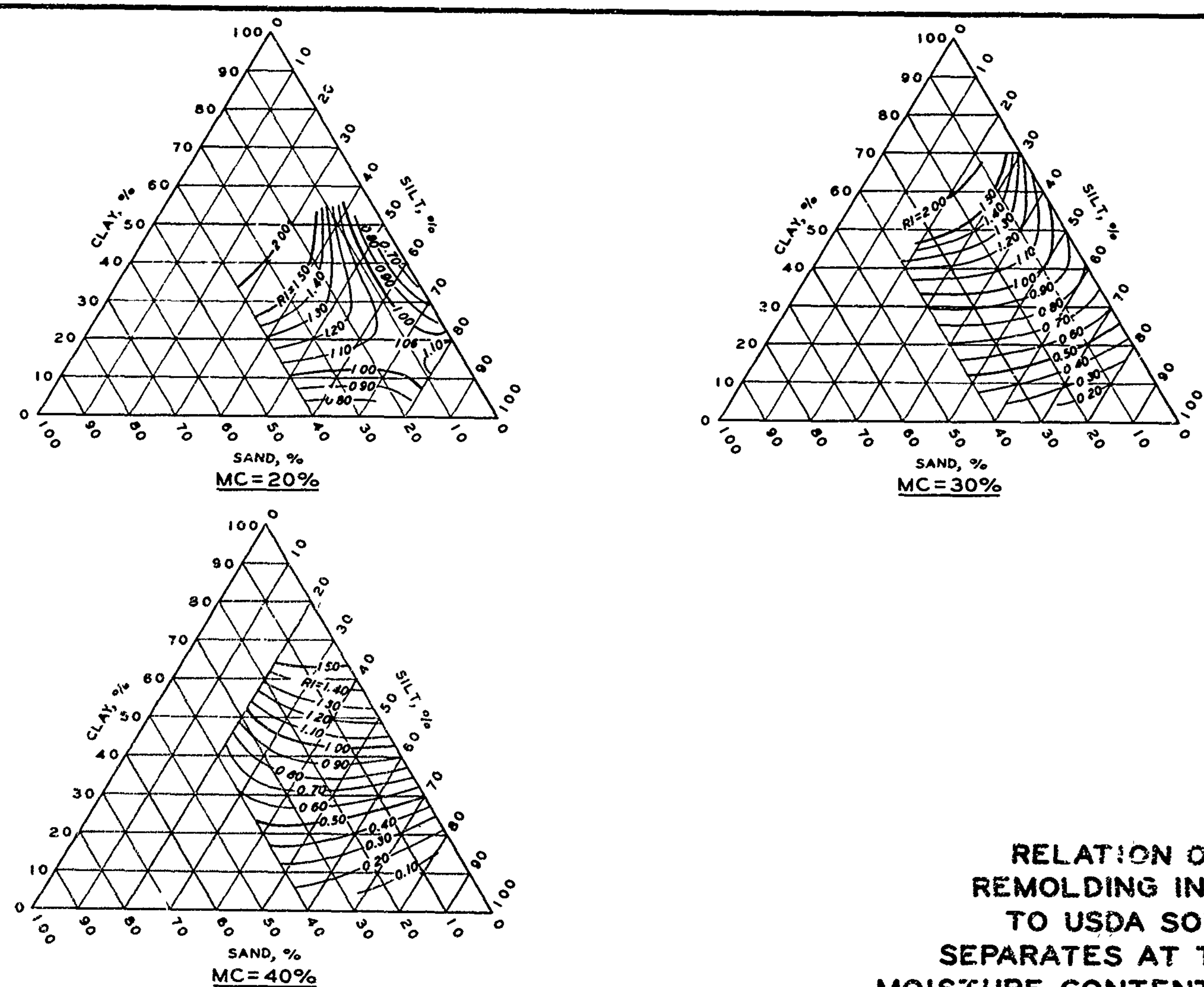
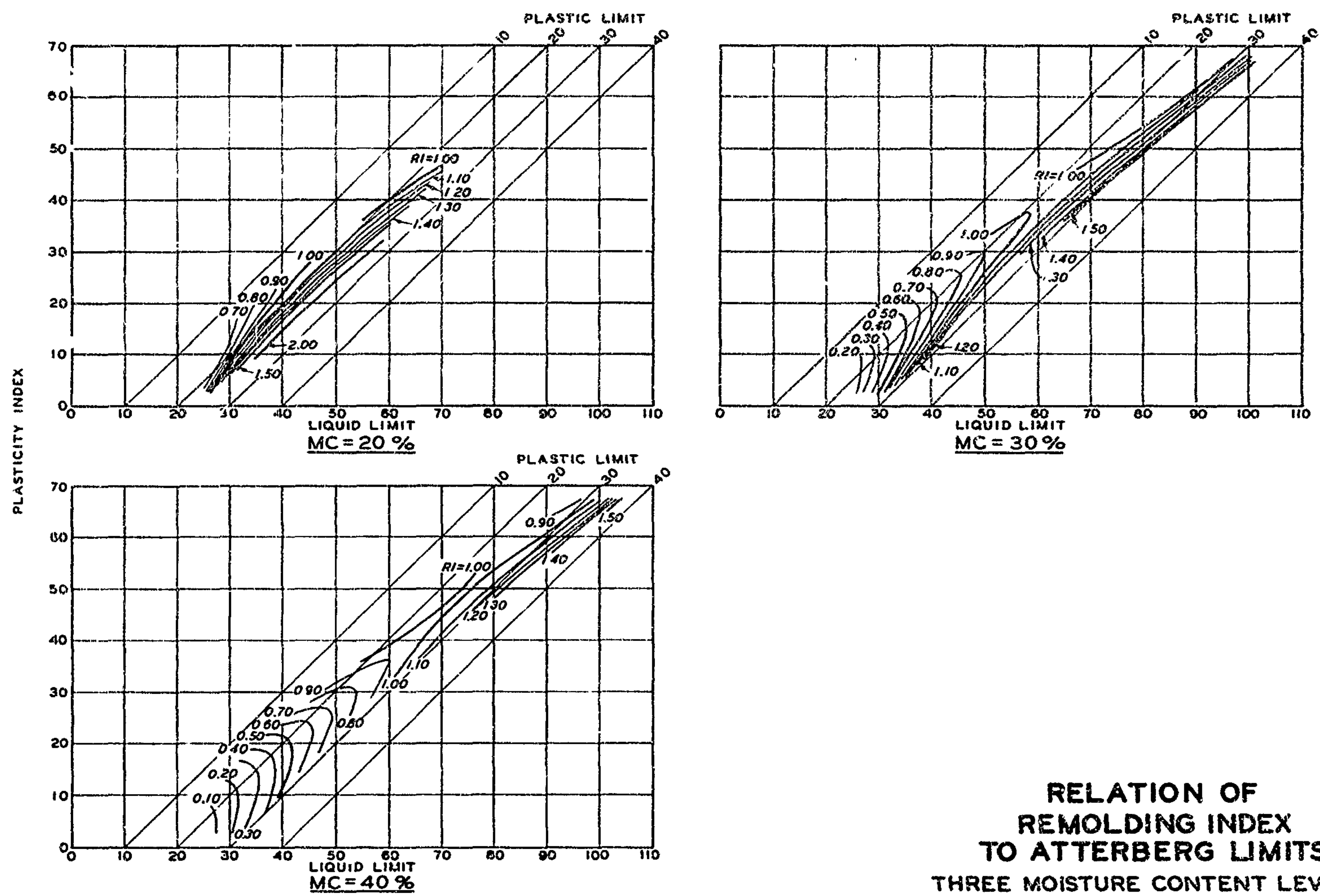

RELATION OF
RI COEFFICIENT TO
PLASTICITY INDEX,
ORGANIC MATTER CONTENT,
AND DRY DENSITY
MEAN RI
1.00
0.50
0
ORGANIC MATTER, %
2
3
4
5
6
PLASTIC TY INDEX
20
40
60
80
DRY DENSITY, PCF
50
60
70
80
90
100
110

PLATE 24



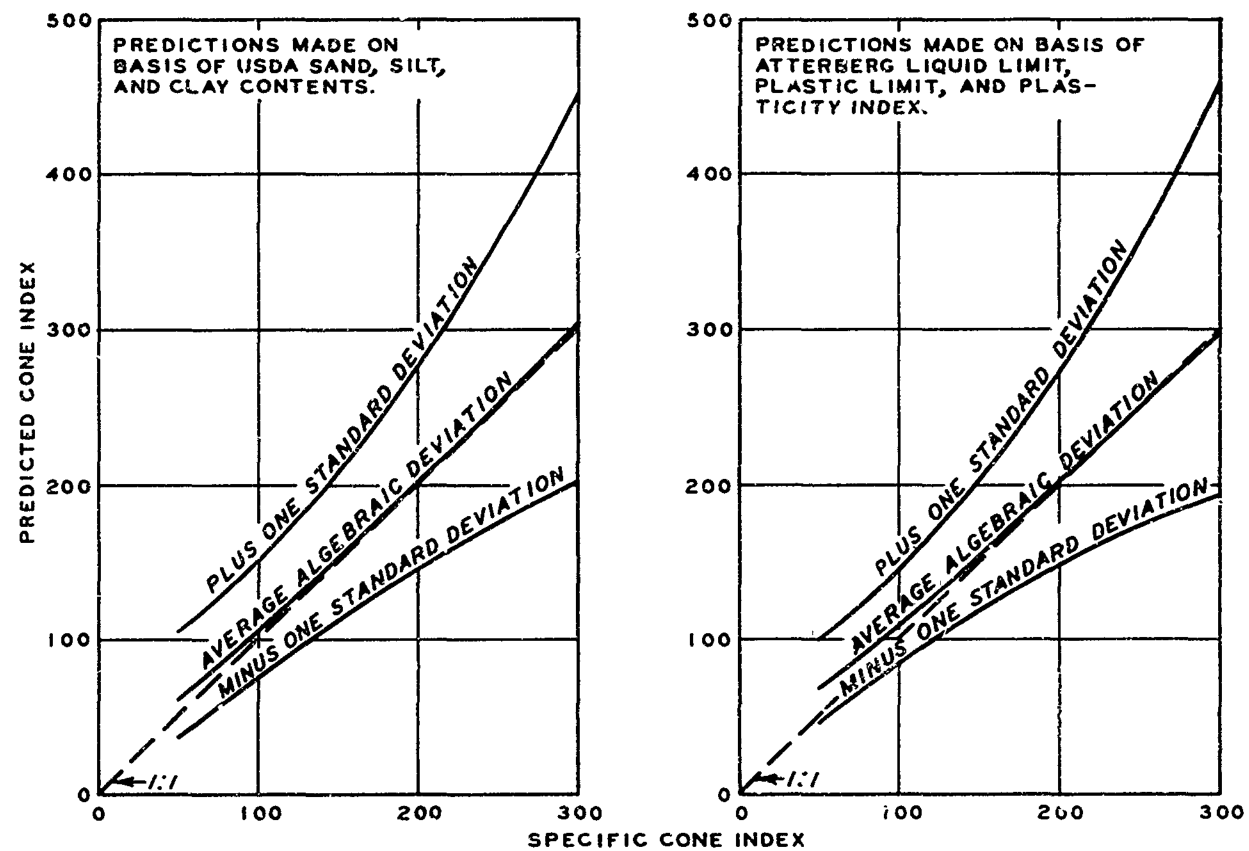
RELATION OF
REMOLDING INDEX
TO USDA SOIL
SEPARATES AT THREE
MOISTURE CONTENT LEVELS



RELATION OF REMOLDING INDEX TO ATTERBERG LIMITS

THREE MOISTURE CONTENT LEVELS

PLATE 26



CONE INDEX
PREDICTION ACCURACY
USDA SOIL SEPARATES
ATTERBERG LIMITS

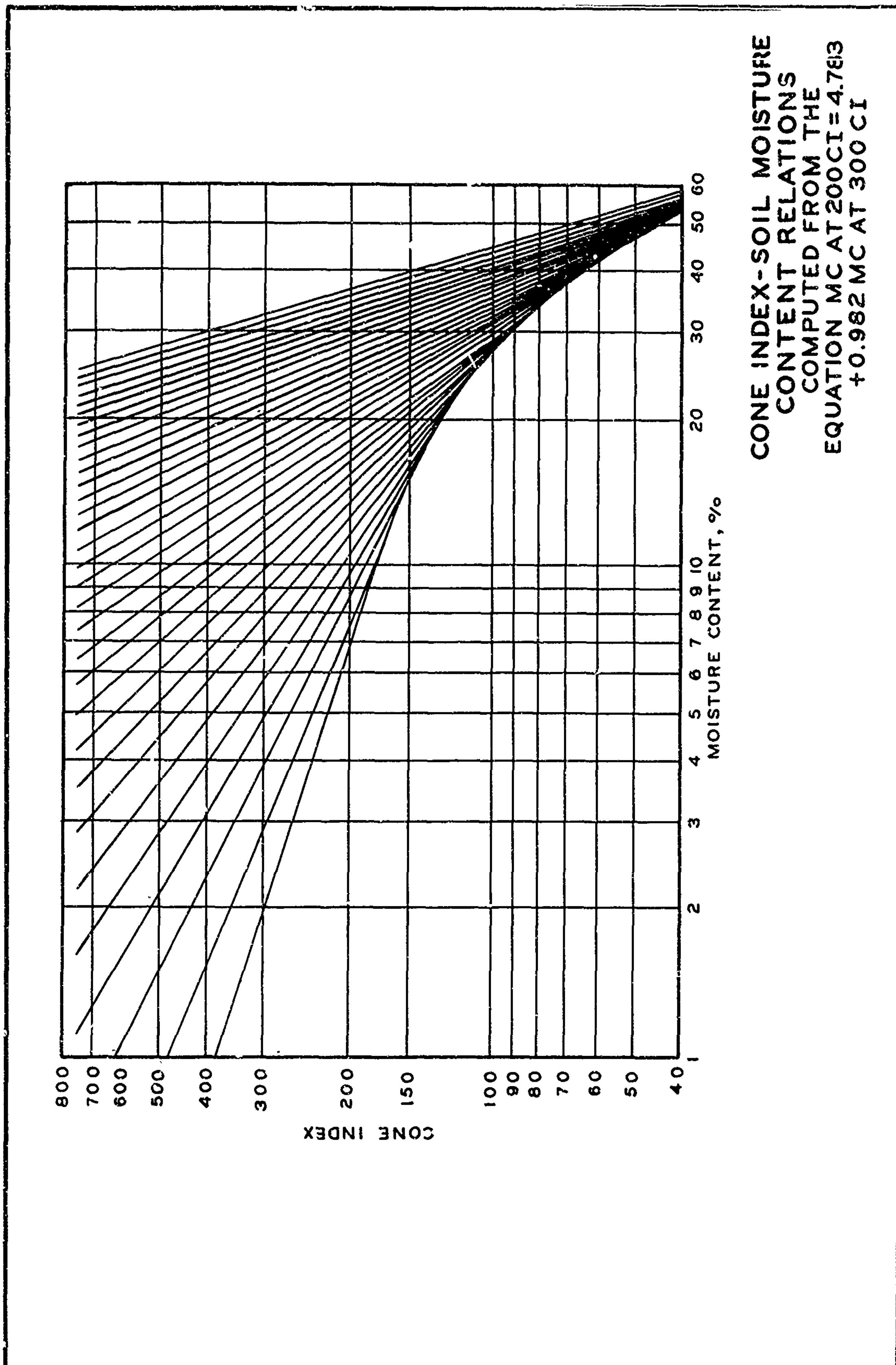
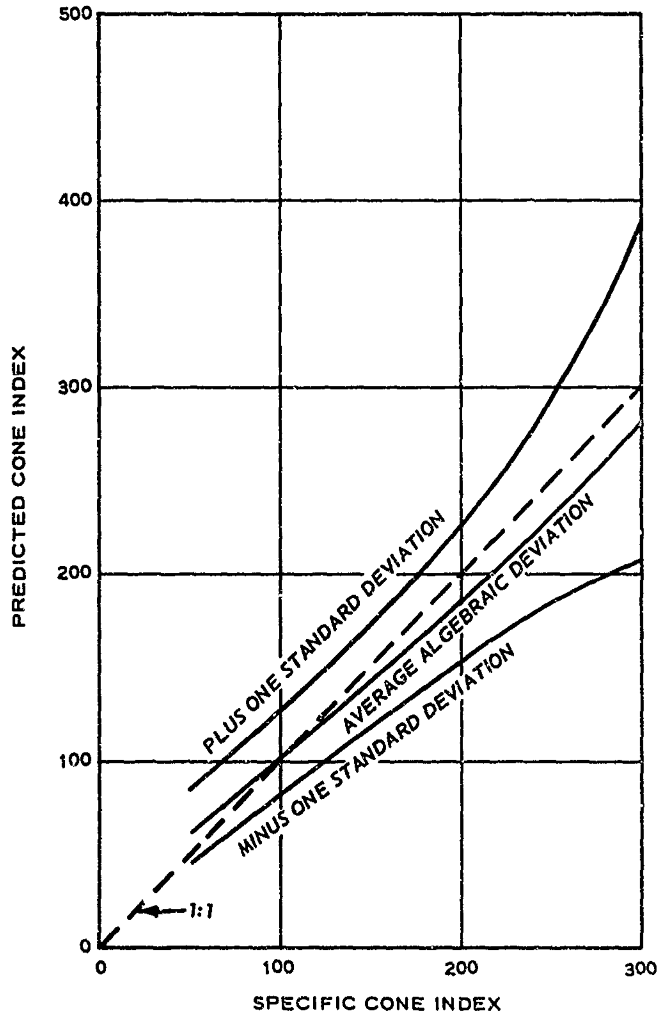
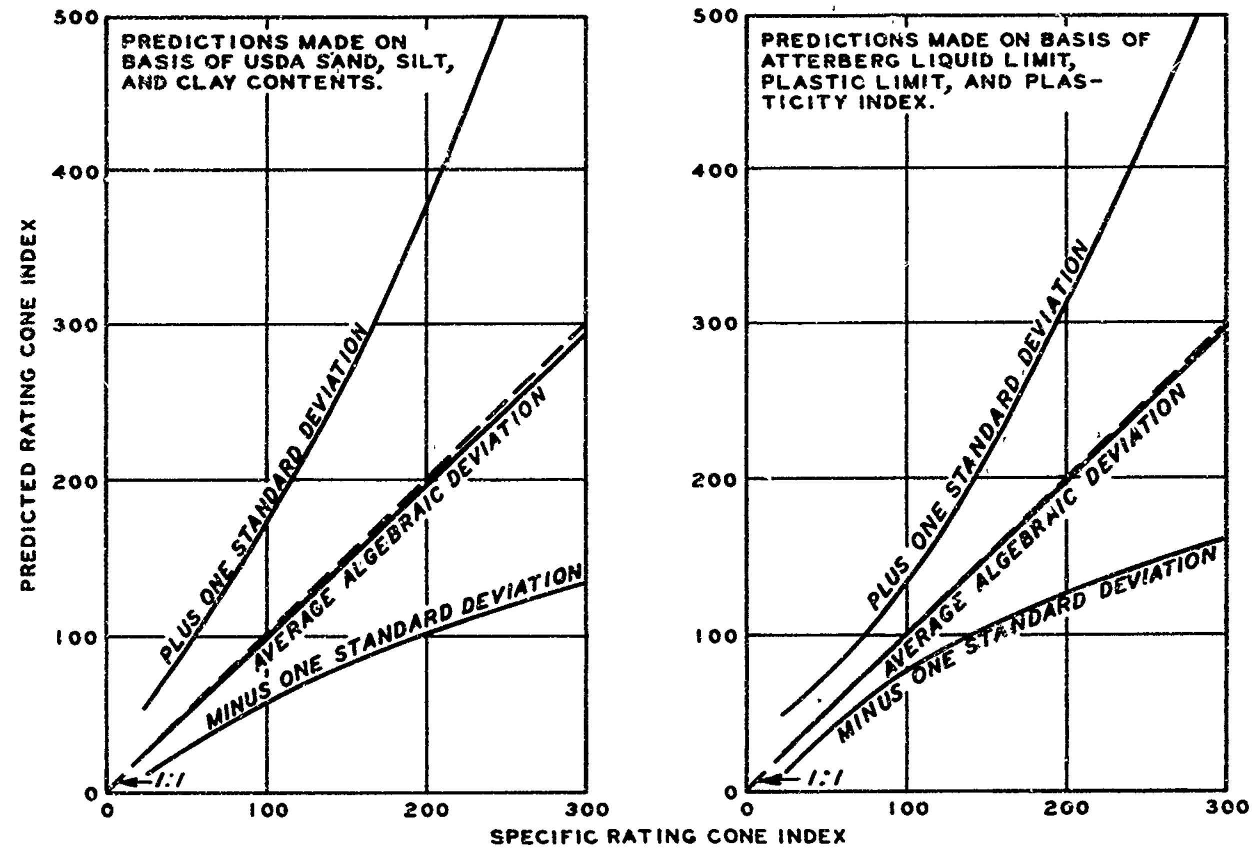

CONE INDEX-SOIL MOISTURE CONTENT RELATIONS
COMPUTED FROM THE EQUATION MC AT 200 CI = 4.783 + 0.982 MC AT 300 CI
MOISTURE CONTENT, %
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60
CONE INDEX
800 700 600 500 400 300 200 150 100 90 80 70 60 50 40

PLATE 28

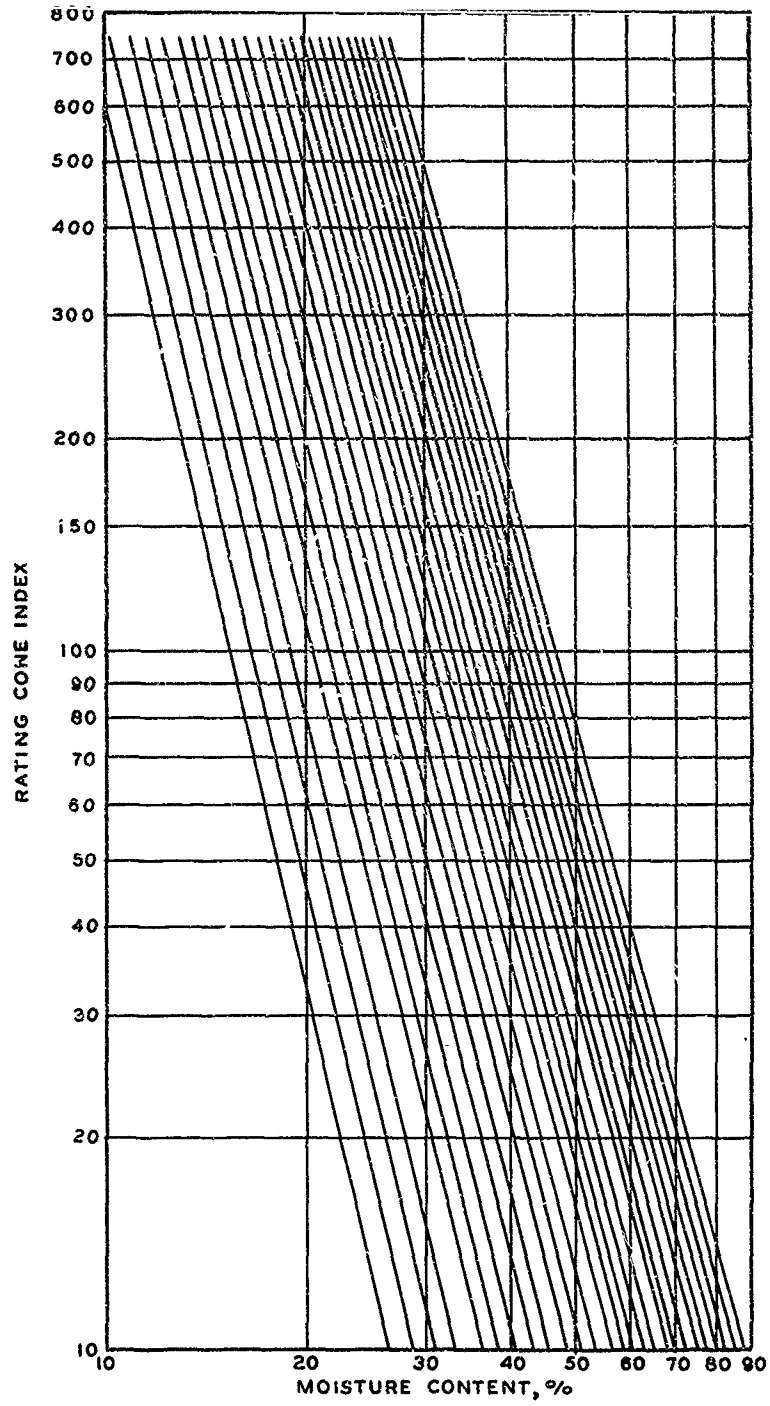


CONE INDEX
PREDICTION ACCURACY
SITE-MEAN CI-MC OBSERVATIONS



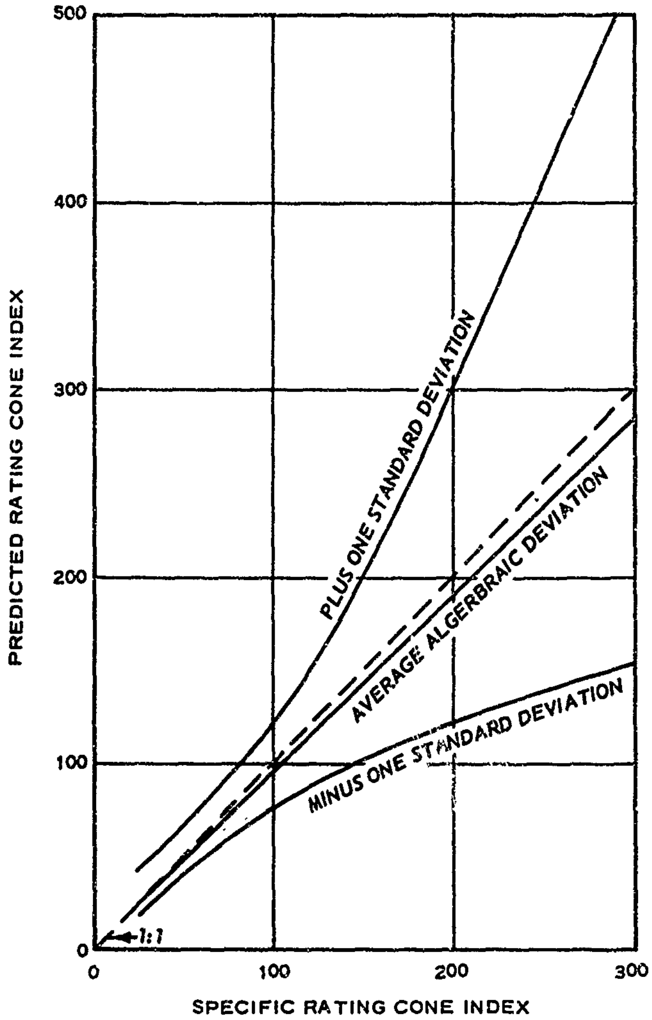
RATING CONE INDEX
PREDICTION ACCURACY
USDA SOIL SEPARATES
ATTERBERG LIMITS

PLATE 30



RATING CONE INDEX - SOIL MOISTURE CONTENT RELATIONS

COMPUTED FROM THE EQUATION MC AT 100 RCI = −0.745 +1.231 MC AT 200 RCI



RATING CONE INDEX
PREDICTION ACCURACY

SITE-MEAN RCI-MC OBSERVATIONS

PLATE 32

APPENDIX A: BASIC DATA

1. Included in this appendix are tables of site characteristics, soil physical properties, and soil moisture-strength data. The methods used to obtain values are also set forth.

Site Characteristics

2. Table A1 gives the location, elevation, slope, aspect, topographic position, drainage characteristics, wetness index, land use, and vegetation of each site. The location is indicated by the nearest town, state, latitude, and longitude as determined from maps.

3. The percent slope and aspect were measured with an Abney level and hand compass. The topographic position was indicated as upland, terrace, or bottomland; modifications of these basic positions were indicated by additional descriptors such as ridge, upper slope, flat, etc.

4. Surface and internal drainages were classified as good, moderate, or poor. The wetness index is an arbitrary classification of sites into five groups on the basis of either minimum depth to water table or maximum depth of infiltration. The classification is used as an indicator of the maximum moisture content that can be attained in the 0- to 12-in. layer; the wetness index ranges from 0 for soils in arid regions to 4 for soils subject to near saturation. Depth to water in observation wells, soil morphological features, soil moisture-tension relations, weather, and vegetation were used as indicators in establishing wetness index classes.

5. Included under land use are disturbances of the land such as cultivation or grazing. If no evidence of use during the preceding five years was apparent, the site was considered to be undisturbed.

Soil Physical Properties

6. Soil physical properties of the 6- to 12-in. layer for each site are listed in table A2. Included are USDA and USCS grain size fractions, Atterberg limits, organic matter content, dry density, and USCS and USDA

soil classes. All properties except dry density were obtained from a composite of five bulk samples for sites numbered 129 through 136, and from a composite of two bulk samples for all other sites.

7. The mechanical compositions of soils were determined at the WES by a combination sieve and hydrometer analysis; grain size fractions are expressed as percent of dry weight. USDA sand (0.05 to 2 mm), silt (0.002 to 0.05 mm), and clay (<0.002 mm) contents are based on that soil passing a No. 10 U. S. standard sieve, whereas fines (<0.074 mm) content is based on the whole soil.

8. The Atterberg limits were determined at the WES. Organic matter content determinations were made at the Mississippi Agricultural Experiment Station. Values are expressed as percent of dry weight. Results for most soils were determined by a modified Walkley, rapid, dichromate oxidation method. If organic matter contents as determined by this method were greater than 5 percent, the loss-on-ignition method following modified procedures of the Association of Agricultural Chemists was used.

9. Undisturbed core samples were used in determining dry density values. Sampling frequency and equipment used are listed below.

Site No. Range	No. of Sites	Sampling Equipment Used	No. of Collections	No. of Samples per Collection
14-35	22	Trafficability sampler	Every visit possible	4
1-13 38-128 150-156	65	Modified San Dimas sampler	1	2
129-136	8	Modified San Dimas sampler	1	5

Use of the trafficability sampler for obtaining samples is discussed in Appendix B; procedures for using the San Dimas sampler have been set forth by Broadfoot.[12*] Dry density values shown in table A2 are in pounds per cubic foot; for a given site the value shown is the average of all samples

* Raised numbers refer to similarly numbered items in the Literature Cited at the end of the main text.

taken. (A value was not determined for site 17.)

10. USCS classes are differentiated on the basis of soil textural and plasticity characteristics. The system is used primarily to classify soils from an engineering construction standpoint. USDA textural classes are based solely on soil texture. Classification criteria are set forth in the USDA Soil Survey Manual.[13]

Soil Moisture-Strength Data

11. Soil moisture content (MC) and soil strength data (CI, RI, and RCI) of the 6- to 12-in. layer for each site are shown in table A3. Equipment used and procedures followed in measuring soil strength are discussed in Appendix B. The trafficability sampler, described in Appendix B, was used to obtain gravimetric moisture samples.

12. Marked differences existed in site areas and the number of soil moisture and strength observations made at a site, as shown below.

Site No. Range	No. of Sites	Site Area sq ft	No. of Observations per Visit MC	CI	RI
14-35	22	1600	4	12	4
1-13 38-128 150-156	65	72	4	6	4
129-136	8	440	5	20	5

The relation between size of area and number of observations is important because the reliability of data is to a large extent dependent on sampling intensity. Differences in the reliability of data can be compensated for statistically through use of weighted analyses. This was not done in this report because such analyses are complicated and because of the large amount of data utilized.

13. Included for each site in table A3 are the dates of visits and average values of MC (expressed in percent dry weight), CI, RI, and RCI for each visit.

Table A1

Site Descriptive Data

Site No.	Nearest Town	State	Latitude	Longitude	Elevation ft, msl	Slope, %	Aspect	Position*	Drainage Surface	Drainage Internal	Wetness Index	Land Use	Vegetation
1	Vicksburg	Mississippi	32°21'	90°51'	300	10	E	U-Upper slope	Good	Moderate	2	Hay	Herbaceous
2	Vicksburg	Mississippi	32°17'	90°54'	100	0	--	B-Flat	Moderate	Moderate		Hay	Herbaceous
[illegible]	Mound	Louisiana	32°20'	91°00'	90	0	--	B-Flat	Moderate	Poor	4	Grazed	Herbaceous
[illegible]	Vicksburg	Mississippi	32°1[illegible]'	90°52'	200	0	--	B-Flat	Moderate	Moderate	4	Hay	Herbaceous
7	Vicksburg	Mississippi	32°1[illegible]'	90°52'	200	5	[illegible]	[illegible]-Ridge	Good	Good	2	Undisturbed	Hardwood forest
8	Vicksburg	Mississippi	32°18'	[illegible]°52'	200	12	E	U-Ridge	Good	Good	[illegible]	Grazed	15-yr pine forest
9	Ellisville	Mississippi	31°34'	[illegible]°09'	225	0	--	T-Upper slope	Moderate	Poor	2	Grazed	Herbaceous and scrub trees
10	Ellisville	Mississippi	31°34'	[illegible]	225	5	[illegible]	T-Lower slope	Poor	Poor		Grazed	Herbaceous and scrub trees
12	Laurel	Mississippi	31°40'	[illegible]°14'	250	5	[illegible]	[illegible]-Lower slope	Moderate	Poor		Logged	Herbaceous and trees
[illegible]	[illegible]	Mississippi	32°05'	[illegible]°54'	250	0	--	[illegible]-Flat	Poor	Poor		Grazed	Herbaceous
[illegible]	Lafayette	Indiana	40°30'	87°	700	0	--	U-Flat	Poor	Poor	3	Undisturbed	Herbaceous
[illegible]	Lafayette	Indiana	41°	87°	700	[illegible]	--	[illegible]-Flat	Poor	Poor	4	Undisturbed	Herbaceous
[illegible]	Lafayette	Indiana	40°30'	87°	700	0	--	[illegible]-Flat	Poor	Poor	[illegible]	Undisturbed	Herbaceous
17	Lafayette	Indiana	41°	87°	700	[illegible]	--	B-Flat	Poor	Poor	[illegible]	Undisturbed	Bare
[illegible]	Lafayette	Indiana	41°	87°	700	0	--	U-Flat	Poor	Poor	[illegible]	Undisturbed	Herbaceous
19	Lafayette	Indiana	41°	[illegible]°	700	0	--	[illegible]-Flat	Poor	Poor		Undisturbed	Herbaceous
20	Brazil	Indiana	39°	[illegible]°	[illegible]50	[illegible]	--	[illegible]-Flat	Poor	Poor	[illegible]	Undisturbed	Herbaceous
21	Attica	Indiana	40°30'	[illegible]	[illegible]	2		[illegible]-Lower slope	Moderate	Poor	4	Undisturbed	Herbaceous
22	Rapid City	South Dakota	44°	103°	3,200	[illegible]	--	T-Flat	Moderate	Moderate		Grazed	Herbaceous
23	Rapid City	South Dakota	44°	103°	3,260	[illegible]	--	T-Flat	Poor	Poor		Grazed	Herbaceous
24	Rapid City	South Dakota	44°	103°	[illegible],260	[illegible]	--	[illegible]-Upper slope	Good	Moderate	2	Grazed	Herbaceous
25	Rapid City	South Dakota	44°	103°	3,260	[illegible]	--	T-Upper slope	Moderate	Moderate	[illegible]	Grazed	Herbaceous
26	Lincoln	Nebraska	41°	97°	1,194	[illegible]	--	B-Flat	Poor	Poor		Grazed	Herbaceous
27	Lincoln	Nebraska	41°	97°	1,194	[illegible]	--	T-Flat	Good	Good	2	Grazed	Herbaceous
28	Lincoln	Nebraska	41°	97°	1,194	[illegible]	--	B-Flat	Poor	Poor		Grazed	Herbaceous
29	Valparaiso	Nebraska	41°	[illegible]°	1,1[illegible]0	[illegible]	--	B-Flat	Good	Poor	[illegible]	Undisturbed	Herbaceous
30	Columbia	South Carolina	34°00'	81°03'	300	0	--	B-Flat	Moderate	Poor	[illegible]	Undisturbed	Herbaceous
31	Columbia	South Carolina	33°57'	81°03'	300	0	--	B-Flat	Moderate	Poor	4	Undisturbed	Herbaceous
32	Columbia	South Carolina	33°57'	81°03'	300	0	--	T-Flat	Moderate	Poor	3	Undisturbed	Herbaceous
33	Columbia	South Carolina	33°57'	81°0[illegible]'	300	0	--	T-Flat	Poor	Poor	3	Undisturbed	Herbaceous
34	Carlisle	South Carolina	34°36'	81°20'	500	[illegible]	--	[illegible]-Flat	Poor	Poor	4	Undisturbed	Herbaceous
[illegible]	Columbia	South Carolina	33°57'	81°03'	300	0	--	T-Flat	Moderate	Poor	3	Undisturbed	Herbaceous
[illegible]	Nacogdoches	Texas	31°30'	[illegible]	225	[illegible]	[illegible]	T-Upper slope	Good	Good	2	Undisturbed	Pine-hardwood forest
[illegible]	Poplar Bluff	Missouri	[illegible]°54'	[illegible]°19'	500	[illegible]	[illegible]	[illegible]-Ridge	Good	Moderate	2	Undisturbed	Hardwood forest
41	Marianna	Florida	30°25'	[illegible]	140	[illegible]	--	[illegible]-Lower slope	Good	Good	2	Undisturbed	Scrub oak and [illegible]
47	Union	South Carolina	34°37'	[illegible]	500	[illegible]	--	U-Upper slope	Moderate	Moderate	[illegible]	Undisturbed	Herbaceous
[illegible]	Union	South Carolina	34°[illegible]2'	[illegible]	500		--	U-Upper slope	Moderate	Moderate	2	Undisturbed	15-yr pine forest
[illegible]1	Glendora	California	34°12'	117°[illegible]'	2,[illegible]0	[illegible]		[illegible]-Upper slope	Good	Good	[illegible]	Undisturbed	Scrub oak
[illegible]	State College	Mississippi	33°27'	[illegible]	42[illegible]	[illegible]	[illegible]	U-Upper slope	Moderate	Poor	[illegible]	Undisturbed	Herbaceous
[illegible]	Coshocton	Ohio	40°22'	[illegible]	1,1[illegible]	12	E	U-Upper slope	Good	Good	2	Cultivated	Herbaceous
[illegible]	Coshocton	Ohio	40°22'	[illegible]	[illegible]	[illegible]	[illegible]	U-Upper slope	Moderate	Poor		Cultivated	Herbaceous
2	East Lansing	Michigan	[illegible]°42'	[illegible]°28'	[illegible]	[illegible]		U-Upper slope	Good	Good	[illegible]	Cultivated	Herbaceous
[illegible]	[illegible] River	[illegible]	[illegible]°21'	[illegible]	2,[illegible]		--	T-Flat	Poor	Poor		Grazed	Herbaceous
1	Crossett	Arkansas	[illegible]	[illegible]°55'	[illegible]	0	--	T-Flat	Poor	Poor		Undisturbed	Pine-hardwood forest
2	Crossett	Arkansas	33°[illegible]	[illegible]	[illegible]	[illegible]	--	T-Flat	Poor	[illegible]		Grazed	Herbaceous
[illegible]	Crossett	Arkansas	33°0[illegible]'	[illegible]°[illegible]2'	[illegible]	[illegible]	--	B-Flat	Moderate	Poor		Undisturbed	Hardwood forest
[illegible]	Crossett	Arkansas	[illegible]	[illegible]	[illegible]	[illegible]	--	T-Depression	Poor	Poor		Undisturbed	Pine-hardwood forest
[illegible]	[illegible]	[illegible]	[illegible]	10[illegible]°20'	[illegible]		[illegible]	U-Upper slope	Good	Good	[illegible]	Grazed	Herbaceous
[illegible]	[illegible]	[illegible]	[illegible]	10[illegible]°20'	[illegible]	[illegible]	[illegible]	U-Upper slope	Good	Good	[illegible]	Grazed	Herbaceous
[illegible]	[illegible]	[illegible]	[illegible]	10[illegible]°[illegible]4'	[illegible],1[illegible]0	[illegible]	[illegible]	T-Flat	Good	[illegible]		Grazed	Herbaceous

(Continued)

* U = [illegible]

Table A1 (Concluded)

[illegible]	Location				Elevation	Topography			Drainage		Wetness Index	Land Use	Vegetation
	Nearest Town	State	Latitude	Longitude	ft, msl	Slope, %	Aspect	Position	Surface	Internal			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	U-Upper slope	Good	Good	[illegible]	Grazed	Sparse herbaceous
[illegible]	[illegible]	New Mexico	35°31'	[illegible]	[illegible]	7	[illegible]	U-Upper slope	Good	Good	[illegible]	Grazed	Sparse herbaceous
[illegible]	Rhinelander	Wisconsin	[illegible]	[illegible]	1,500	[illegible]	--	U-Flat	Moderate	Poor	4	Hay	Herbaceous
[illegible]	Rhinelander	Wisconsin	[illegible]	[illegible]	1,500	0	--	U-Flat	Moderate	Poor	4	Undisturbed	Aspen forest
[illegible]	Rhinelander	Wisconsin	[illegible]	[illegible]	1,450	4	N	U-Lower slope	Moderate	Poor	2	Undisturbed	Pine and aspen forest
[illegible]	Rhinelander	Wisconsin	45°40'	89°48'	1,465	9	N	U-Upper slope	Good	Good	2	Undisturbed	Pine and aspen forest
[illegible]	Rhinelander	Wisconsin	45°40'	89°48'	1,540	4	E	U-Upper slope	Good	Good	2	Undisturbed	Herbaceous
[illegible]	Rhinelander	Wisconsin	45°40'	89°48'	1,550	0	--	U-Flat	Moderate	Good	2	Hay	Herbaceous
[illegible]	Rhinelander	Wisconsin	45°40'	89°48'	1,550	0	--	U-Flat	Moderate	Good	2	Undisturbed	Aspen forest
[illegible]	Rhinelander	Wisconsin	45°40'	89°48'	1,500	0	--	U-Flat	Moderate	Poor	3	Undisturbed	Aspen forest
[illegible]	Rhinelander	Wisconsin	45°40'	89°48'	1,500	0	--	U-Flat	Moderate	Poor	3	Undisturbed	Herbaceous
[illegible]	Ashland	Wisconsin	46°30'	90°30'	1,500	5	W	U-Lower slope	Poor	Poor	3	Grazed	Herbaceous
[illegible]	Ashland	Wisconsin	46°30'	90°30'	1,520	4	N	U-Upper slope	Moderate	Moderate	2	Hay	Herbaceous
[illegible]	Mesa La[illegible]	Colorado	39°02'	108°06'	10,460	7	W	U-Upper slope	Good	Good	2	Undisturbed	Herbaceous
[illegible]	[illegible]	Colorado	39°03'	108°12'	10,000	4	N	U-Ridge	Good	Good	2	Undisturbed	Herbaceous
[illegible]	[illegible]	Colorado	39°02'	108°06'	10,430	0	--	U-Depression	Poor	Poor	4	Grazed	Herbaceous
[illegible]	[illegible]	Colorado	39°02'	107°57'	[illegible],700	10	SW	U-Upper slope	Good	Good	2	Grazed	Aspen and herbaceous
[illegible]	[illegible]	Colorado	[illegible]	107°57'	[illegible],200	20	S	U-Upper slope	Good	Good	2	Grazed	Aspen and herbaceous
[illegible]	[illegible]	Colorado	[illegible]	107°57'	[illegible],700	[illegible]	[illegible]	U-Lower slope	Good	Good	2	Grazed	Scrub oak and shrub
[illegible]	[illegible]	Colorado	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	T-Lower slope	Good	Good	2	Undisturbed	Aspen and herbaceous
[illegible]	[illegible]	Colorado	[illegible]	[illegible]	[illegible]	20	[illegible]	T-Upper slope	Good	Good	2	Undisturbed	Scrub oak and herbaceous
[illegible]	[illegible]	Colorado	[illegible]	[illegible]	[illegible]		--	T-Lower slope	Good	Good	2	Undisturbed	Pine and herbaceous
[illegible]	[illegible]	Colorado	[illegible]	[illegible]	[illegible]	4		T-Lower slope	Good	Moderate	1	Undisturbed	Sparse herbaceous
[illegible]	[illegible]	Colorado	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]-Ridge	Good	Moderate		Undisturbed	Bare
12	[illegible]	Mississippi	[illegible]	[illegible]	[illegible]	[illegible]	--	U-Flat	Good	Good	2	Hay	Herbaceous
[illegible]	[illegible]	Louisiana	[illegible]	[illegible]	[illegible]	5	W	U-Upper slope	Good	Moderate	2	Grazed	Herbaceous
[illegible]	[illegible]	Louisiana	[illegible]	[illegible]	[illegible]	0	--	U-Depression	Poor	Poor	4	Grazed	Herbaceous
[illegible]	[illegible]	Illinois	37°27'	[illegible]	[illegible]	[illegible]	[illegible]	T-Upper slope	Good	Moderate	2	Undisturbed	Pine forest
[illegible]	Oxford	Mississippi	[illegible]	[illegible]	355	[illegible]	[illegible]	U-Upper slope	Poor	Moderate	2	Undisturbed	15-yr pine forest
[illegible]	Oxford	Mississippi	[illegible]	[illegible]	[illegible]	15	[illegible]	U-Upper slope	Good	Moderate	2	Undisturbed	15-yr pine forest
12	[illegible]	Mississippi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	U-Upper slope	Good	Good	2	Undisturbed	15-yr pine forest
[illegible]	[illegible]	Mississippi	32°27'	90°50'	[illegible]	0	--	B-Flat	Good	Good	4	Grazed	Herbaceous
[illegible]	[illegible]	Mississippi	32°32'	90°45'	100	3	[illegible]	T-Slope	Good	Moderate	4	Grazed	Herbaceous
[illegible]	Valley Farm	Mississippi	32°35'	90°50'	[illegible]	0	--	B-Flat	Moderate	Moderate	2	Cultivated	Cotton
[illegible]	Valley Farm	Mississippi	32°35'	90°50'	[illegible]	0	--	B-Flat	Moderate	Poor	4	Grazed	Herbaceous
[illegible]	[illegible]ward	Mississippi	32°41'	90°55'	95	0	--	B-Flat	Moderate	Moderate	2	Cultivated	Cotton
[illegible]	[illegible]ward	Mississippi	32°43'	91°00'	90	0	--	B-Flat	Moderate	Poor	4	Undisturbed	Hardwood forest
[illegible]	Eagle Lake	Mississippi	32°36'	91°00'	90	0	--	B-Flat	Moderate	Poor	4	Grazed	Herbaceous
[illegible]	Eagle Lake	Mississippi	32°33'	91°04'	95	0	--	B-Flat	Moderate	Moderate	2	Grazed	Herbaceous
[illegible]	Miles City	Montana	46°23'	101°51'	2,400	0	--	T-Flat	Poor	Poor	3	Grazed	Herbaceous
[illegible]	Miles City	Montana	46°23'	105°54'	2,400	0	--	B-Flat	Poor	Poor	3	Grazed	Herbaceous
[illegible]	Miles City	Montana	46°21'	105°55'	2,400	0	--	T-Flat	Moderate	Poor	2	Grazed	Herbaceous
[illegible]	Rockford	Washington	47°27'	117°05'	2,450	10	S	U-Upper slope	Good	Poor	3	Grazed	Pine forest
[illegible]	Rockford	Washington	47°26'	117°06'	[illegible]	0	--	B-Flat	Poor	Moderate	4	Cultivated	Herbaceous
[illegible]	Rockford	Washington	47°25'	117°11'	2,600	12	[illegible]	U-Upper slope	Good	Moderate	3	Cultivated	Herbaceous

Table A2

Soil Physical Properties, 6- to 12-in. layer

Site No.	Mechanical Analysis, % by wt: USDA Sand	USDA Silt	USDA Clay	USCS Fines	Atterberg Limits: LL	PL	PI	Organic Matter %	Dry Density pcf	Classification: USCS	USDA
1	6	75	19	99	28	23	5	0.8	85	ML	SiL
2	4	78	18	100	35	27	8	1.2	88	ML	SiL
4	6	49	45	96	60	25	35	1.8	82	CH	SiC
6	4	79	17	100	38	26	12	1.5	82	ML	SiL
7	4	80	16	100	25	24	1	0.7	80	ML	SiL
8	6	72	22	99	36	23	13	0.4	84	CL	SiL
9	30	61	9	77	19	17	2	1.0	95	ML	SiL
10	30	57	13	77	24	18	6	0.8	94	CL-ML	SiL
12	22	55	23	84	31	18	13	0.9	86	CL	SiL
13	18	36	46	83	68	23	45	0.8	76	CH	C
14	9	65	26	96	38	21	17	--	94	CL	SiL
15	12	63	25	91	55	20	35	1.9	86	CH	SiL
16	18	52	30	87	45	25	20	3.5	90	CL	SiCL
17	13	62	25	89	82	42	40	--	--	OH	SiL
18	8	58	34	96	54	18	36	--	91	CH	SiCL
19	18	51	31	88	52	24	28	2.8	98	CH	SiCL
20	12	68	20	91	33	21	12	--	94	CL	SiL
21	9	69	22	96	34	21	13	2.3	93	CL	SiL
22	46	38	16	69	31	22	9	2.9	82	CL	L
23	15	36	49	90	58	25	33	1.6	90	CH	C
24	14	54	32	94	33	19	14	4.2	86	CL	SiCL
25	51	40	9	60	29	24	5	3.8	85	ML	L
26	6	70	24	99	49	22	27	3.4	80	CL	SiL
27	9	79	12	99	48	22	26	3.1	80	CL	SiL
28	12	68	20	97	34	18	16	0.7	93	CL	SiL
29	9	63	28	97	54	23	31	4.1	78	CH	SiCL
30	29	47	24	80	42	24	18	1.0	91	CL	L
31	23	47	30	88	43	23	20	1.1	93	CL	CL
32	14	29	57	91	60	26	34	0.9	92	CH	C
33	23	37	40	88	43	19	24	0.9	99	CL	C
34	10	20	70	92	107	28	79	0.9	82	CH	C
35	60	30	10	49	--	--	NP*	--	106	SM	SL
38	60	35	5	53	16	--	NP	0.2	84	ML	SL
39	14	71	15	90	28	20	8	0.7	91	CL	SiL
41	94	4	2	7	16	--	NP	0.3	95	SM	S
47	29	20	51	72	57	24	33	0.7	70	CH	C
48	35	23	42	66	63	28	35	0.5	89	CH	C
51	65	30	5	43	21	--	NP	0.4	82	SM	SL
58	36	24	40	72	53	23	30	1.7	87	CH	C
60	29	49	22	83	30	20	10	0.9	90	CL	L
61	13	65	22	93	32	22	10	1.2	88	CL	SiL
62	50	35	15	67	20	17	3	0.5	93	ML	L
67	12	65	23	93	39	31	8	0.7	59	ML	SiL
71	19	67	14	93	27	20	7	0.5	91	CL-ML	SiL
72	16	73	11	95	26	22	4	0.8	88	CL-ML	SiL
74	8	70	22	95	37	25	12	1.4	85	ML	SiL
75	42	53	5	68	18	--	NP	0.6	99	ML	SiL
76	22	51	27	92	46	22	24	1.3	90	CL	SiL
79	37	40	23	86	34	17	17	1.0	90	CI	L
81	57	23	20	57	25	15	10	0.5	103	CL	SCL

(Continued)

* NP = nonplastic.

Table A2 (Concluded)

Site No.	Mechanical Analysis, % by wt USDA Sand	Silt	Clay	USCS Fines	Atterberg Limits LL	PL	PI	Organic Matter %	Dry Density pcf	Classification USCS	USDA
83	37	40	23	73	48	22	26	1.9	95	CL	L
85	71	18	11	42	22	17	5	0.8	97	SC-SM	SL
88	28	66	6	82	26	22	4	2.1	84	CL-ML	SiL
89	22	72	6	88	28	24	4	1.9	69	ML	SiL
90	91	7	2	11	15	--	NP*	1.5	95	SM	S
91	93	6	1	9	14	--	NP	0.8	89	SM	S
94	84	15	1	19	15	--	NP	1.7	95	SM	LS
95	37	57	6	76	22	19	3	1.1	87	ML	SiL
96	48	47	5	59	20	16	4	0.8	80	CL-ML	SL
97	25	69	6	86	25	21	4	1.0	72	CL-ML	SiL
98	26	69	5	83	26	22	4	1.6	77	CL-ML	SiL
101	30	37	33	76	45	19	26	0.9	86	CL	CL
102	64	31	5	43	17	15	2	1.3	92	SM	SL
103	18	66	16	94	36	26	10	3.7	61	ML	SiL
105	18	64	18	93	41	26	15	4.0	60	ML	SiL
108	12	76	12	98	64	48	16	5.8	57	MH	SiL
109	44	38	18	62	36	22	14	3.6	72	CL	L
110	42	42	16	65	39	25	14	5.0	67	CL	L
112	34	51	15	78	38	25	13	5.3	65	ML	SiL
114	20	65	15	96	42	28	14	5.5	60	ML	SiL
115	31	49	20	82	29	19	10	3.7	70	CL	L
116	46	42	12	66	49	44	5	4.2	59	ML	L
117	10	55	35	93	36	17	19	0.9	92	CL	SiCL
119	11	49	40	99	38	19	19	0.6	97	CL	SiC
120	9	71	20	93	33	23	10	0.5	92	CL	SiL
123	32	48	20	74	28	18	10	0.6	94	CL	L
124	7	74	19	95	--	--	NP	1.1	89	ML	SiL
125	10	76	14	97	32	23	9	0.5	84	ML	SiL
126	6	60	34	98	47	24	23	0.7	91	CL	SiCL
127	17	58	25	91	30	20	10	0.8	99	CL	SiL
128	9	62	29	96	39	20	19	0.8	93	CL	SiCL
129	7	78	15	99	36	24	12	1.3	91	CL	SiL
130	12	73	15	98	33	22	11	1.6	92	CL	SiL
131	22	59	19	89	36	20	16	1.0	92	CL	SiL
132	3	38	59	99	88	31	57	1.2	76	CH	C
133	5	72	23	99	39	21	18	1.0	92	CL	SiL
134	4	45	51	96	85	30	55	1.7	73	CH	SiC
135	3	54	43	99	73	28	45	1.3	80	CH	SiC
136	0	69	31	100	50	19	31	1.6	88	CH	SiCL
150	10	50	40	95	52	20	32	2.0	89	CH	SiCL
151	14	51	35	93	47	22	25	2.9	85	CL	SiCL
152	17	62	21	90	30	20	10	1.7	84	CL	SiL
153	14	67	19	94	33	22	11	2.0	69	CL	SiL
155	20	67	13	88	34	26	8	3.3	77	ML	SiL
156	16	71	13	94	36	26	10	2.8	71	ML	SiL

* NP = nonplastic.

Table A3

Soil Moisture-Strength Data, [illegible]- to 12-in. Layer

Date	MC, %	CI	RI	RCI
Site 1, Vicksburg, Miss.				
4/3/51	30.8	128		
4/4/51	31.1	127		
4/5/51	28.4	13[illegible]		
4/[illegible]/51	28.[illegible]	132		
4/10/51	29.0	12[illegible]		
4/12/51	29.1	13[illegible]		
4/17/51	27.1	129		
4/19/51	23.2	232		
4/21/51	31.0	102		
4/24/51	28.[illegible]	14[illegible]		
4/26/51*	28.2	17[illegible]	0.67	118
4/26/51*	30.4	128	0.[illegible]4	[illegible]2
4/27/51*	29.1	115	0.56	[illegible]4
4/27/51*	29.5	181	0.53	9[illegible]
4/27/51	25.[illegible]	219		
4/28/51*	29.2	170	0.42	72
4/30/51*	28.4	198	0.[illegible]1	121
5/1/51*	25.6	190	0.48	[illegible]1
5/1/51*	26.6	201	0.45	90
5/2/51*	2[illegible].9	222	0.84	18[illegible]
5/2/51*	2[illegible].1	199	0.48	9[illegible]
5/2/51*	23.[illegible]	300+		
5/2/51*	23.0	25[illegible]		
5/3/51*	2[illegible].4	190	0.45	[illegible]
5/3/51*	28.2	132	0.38	[illegible]0
5/3/51*	26.2	204	0.[illegible]5	133
5/4/51*	[illegible]	180	0.[illegible]2	112
5/4/51*	26.[illegible]	143	0.49	70
5/4/51*	23.8	244		
5/4/51*	25.[illegible]	178	0.4[illegible]	82
5/5/51*	27.0	[illegible]	0.48	80
5/5/51*	24.8	230		
5/7/51*	25.[illegible]	220		
5/7/51*	2[illegible].0	213	0.43	[illegible]2
5/7/51*	24.4	[illegible]	0.53	142
5/8/51*	2[illegible]	1[illegible]8	0.[illegible]4	105
5/9/51*	23.3	2[illegible]0		
5/9/51*	25.[illegible]	210	0.71	149
5/10/51*	25.2	218	0.48	105
5/10/51*	29.3	101	0.[illegible]4	[illegible]5
5/11/51*	27.2	184	0.51	94
5/11/51*	23.7	300+		
5/11/51*	27.7	1[illegible]8	0.43	72
5/11/51*	23.4	175	0.78	13[illegible]
5/11/51*	2[illegible]	147	1.07	157
5/12/51*	25.4	159	0.39	[illegible]2
5/12/51	24.[illegible]	251		
5/14/51*	25.1	1[illegible]9	0.44	74
5/14/51*	23.[illegible]	201		
Site 2, Vicksburg, Miss.				
3/31/51	25.4	23[illegible]		
4/[illegible]/51	25.4	300		
4/10/51	25.1	242		
[illegible]/13/51*	25.2	2[illegible]		
[illegible]/1[illegible]/51*	2[illegible].2	144	0.[illegible]3	[illegible]1
[illegible]/1[illegible]/51	25.4	24[illegible]		
[illegible]/20/51*	2[illegible].3	18[illegible]	0.[illegible]	12[illegible]
[illegible]/21/51	2[illegible].0	17[illegible]	0.[illegible]9	114
[illegible]/2[illegible]/51	2[illegible]	300		
[illegible]/23/51*	25.3	23[illegible]	0.[illegible]2	1[illegible]
[illegible]/29/51*	25.0	2[illegible]		
[illegible]/30/51*	2[illegible].[illegible]	[illegible]		
[illegible]/2/51*	27.[illegible]	[illegible]51		
[illegible]/2/[illegible]2	25.[illegible]	25[illegible]		
[illegible]/[illegible]/52	[illegible].0	2[illegible]4		
[illegible]/14/52	25.[illegible]	2[illegible]2	0.[illegible]	[illegible]
[illegible]/21/52	2[illegible].5	[illegible]0	0.4	
[illegible]/2[illegible]/52	2[illegible]	2[illegible]	0.[illegible]2	[illegible]
Site 2, Vicksburg, Miss. (Cont'd)				
2/4/52	27.2	210	0.[illegible]	145
2/11/52	2[illegible]	232	0.[illegible]0	139
2/18/52	25.9	23[illegible]		
2/25/52	2[illegible].5	192	0.58	111
3/3/52	28.9	207	0.4[illegible]	[illegible]5
3/11/52	27.[illegible]	197	0.50	98
3/17/52	27.1	215	0.42	90
3/24/52	25.[illegible]	241	0.70	1[illegible]9
3/31/52	2[illegible].2	255	0.[illegible]8	173
4/7/52	25.0	2[illegible]0		
4/14/52	2[illegible].5	244		
5/2[illegible]/52	25.9	284		
Site 4, Mound, La.				
4/1/51	33.8	140		
4/3/51	31.4	128		
4/4/51	3[illegible].9	141		
4/5/51	[illegible]2.4	14[illegible]		
4/[illegible]/51	31.9	128		
4/7/51	32.[illegible]	127		
4/11/51	32.7	144		
4/12/51	34.5	140		
4/1[illegible]/51	31.3	144		
4/18/51	31.3	139		
4/19/51	30.8	1[illegible]8		
4/20/51	31.[illegible]	147		
4/24/51	34.[illegible]	151		
5/22/51*	32.8	[illegible]9		
5/23/51*	31.[illegible]	125		
5/24/51*	33.0	132		
5/24/51*	33.2	115		
5/25/51*	33.[illegible]	122		
[illegible]/2[illegible]/51*	32.5	[illegible]23		
5/2[illegible]/51*	31.[illegible]	1[illegible]		
5/29/51*	31.[illegible]	11[illegible]	[illegible].4[illegible]	[illegible]
5/29/51*	31.[illegible]	[illegible]20	0.[illegible]	[illegible]
5/31/51*	29.9	218		
5/31/51*	30.1	17[illegible]	[illegible].24	221
5/31/51*	30.7	[illegible]	1.0[illegible]	1[illegible]5
[illegible]/2/51*	3[illegible].2	1[illegible]3		
[illegible]/2/51*	32.4	14[illegible]		
[illegible]/4/51*	32.[illegible]	153		
[illegible]/4/51*	32.1	1[illegible]2	1.02	1[illegible]5
[illegible]/51*	32.2	143	0.[illegible]5	13[illegible]
[illegible]/51*	31.5	15[illegible]		
[illegible]/51*	32.3	143		
[illegible]/51*	31.2	137		
[illegible]/9/51*	31.4	134		
[illegible]/9/51*	31.4	14[illegible]		
[illegible]/9/51*	33.[illegible]	[illegible]32		
[illegible]/11/51*	33.8	9[illegible]	[illegible].[illegible]	10[illegible]
[illegible]/11/51	29.[illegible]	300+		
[illegible]/12/51*	31.8	[illegible]2		
[illegible]/12/51*	33.[illegible]	[illegible]2		
[illegible]/12/51*	33.0	[illegible]3		
[illegible]/14/51*	32.[illegible]	120		
[illegible]/14/51*	34.1	131	0.[illegible]3	[illegible]2
[illegible]/15/51*	32.3	[illegible]1[illegible]		
[illegible]/15/51*	34.5	[illegible]	0.[illegible]2	74
[illegible]/18/51*	33.4	11[illegible]	0.[illegible]5	1[illegible]3
[illegible]/19/51	32.4	224		
[illegible]/21/51*	31.[illegible]	10[illegible]		
[illegible]/21/51	30.0	1[illegible]		
[illegible]/1[illegible]/51	29.[illegible]	23[illegible]		
1/2/52	33.5	1[illegible]1		
1/7/52	33.2	1[illegible]4		
1/14/52	32.[illegible]	152		
1/21/52	[illegible]	122		
1/2[illegible]/52	33.[illegible]	[illegible]3		
Site 4, Mound, La. (Cont'd)				
2/4/52	33.5	1[illegible]		
2/11/52	32.0	1[illegible]4		
2/1[illegible]/52	33.3	1[illegible]3		
2/25/52	33.2	1[illegible]0		
3/3/52	[illegible].7	172		
3/11/52	3[illegible].4	148		
3/12/52	3[illegible].5	12[illegible]	0.[illegible]	122
3/1[illegible]/52	33.[illegible]	[illegible]		
3/24/52	[illegible]	170		
3/31/52	33.[illegible]	200		
4/14/52	33.8	1[illegible]		
4/21/52	2[illegible].[illegible]	300		
4/25/52	33.0	153	[illegible]	[illegible]1
4/28/52	30.6	1[illegible]		
5/5/52	30.2	300		
5/19/52	33.7	17[illegible]	[illegible]	14[illegible]
5/2[illegible]/52	32.[illegible]	1[illegible]		
[illegible]/2/52	33.5	1[illegible]1		
Site [illegible], Vicksburg, Miss.				
2/2[illegible]/52	35.2	[illegible]2	0.54	[illegible]0
2/28/52	35.4	[illegible]	0.4[illegible]	42
4/[illegible]/52	31.7	151	0.[illegible]7	[illegible]
4/1[illegible]/52	34.[illegible]	[illegible]	0.4[illegible]	[illegible]
[illegible]/22/52	31.[illegible]	144	0.53	[illegible]
4/24/52	[illegible].5	[illegible]	0.5[illegible]	[illegible]
4/2[illegible]/52	31.[illegible]	125	0.4[illegible]	5[illegible]
[illegible]	30.4	4[illegible]	0.4[illegible]	
[illegible]/1[illegible]/52	30.3	1[illegible]2	0.57	[illegible]2
5/2[illegible]/52	32.[illegible]	[illegible]12	0.52	[illegible]
5/2[illegible]/52	32.[illegible]	14[illegible]	0.[illegible]5	[illegible]
[illegible]	2[illegible]	[illegible]		
[illegible]/1[illegible]/52	2[illegible]	[illegible]4	[illegible]	[illegible]
[illegible]	2.[illegible]	2[illegible]5		
[illegible]	[illegible]	1[illegible]		
[illegible]/21/52*	2[illegible]	2[illegible]0	0.[illegible]	13[illegible]
[illegible]/23/52*	2[illegible]	2[illegible]4	0.[illegible]	1[illegible]
[illegible]/24/52	2[illegible]	20[illegible]	0.[illegible]3	[illegible]30
[illegible]/2[illegible]/52*	2[illegible].0	2[illegible]0	[illegible]	1[illegible]2
[illegible]/2[illegible]/52*	[illegible].0	235	[illegible]	1[illegible]0
[illegible]/2[illegible]/52*	2[illegible].2	1[illegible]		
11/2[illegible]/52	[illegible].1	28[illegible]		
12/1/52	2[illegible].1	220		
12/5/52	31.[illegible]	138	0.53	[illegible]3
12/[illegible]/52	31.2	15[illegible]	0.[illegible]	104
[illegible]/12/52	30.[illegible]	[illegible]	0.50	[illegible]
12/15/52	30.2	[illegible]	0.[illegible]4	120
12/1[illegible]/52	2[illegible].	1[illegible]	0.[illegible]1	1[illegible]1
12/22/52	31.[illegible]	1[illegible]4	0.[illegible]2	1[illegible]2
12/2[illegible]/52	30.2	1[illegible]7	0.[illegible]0	112
1/2/53	31.[illegible]	13[illegible]	0.45	1[illegible]
1/[illegible]/53	31.3	1[illegible]5	0.[illegible]1	1[illegible]1
1/[illegible]/53	32.[illegible]	139		
1/12/53	[illegible].2	1[illegible]	0.[illegible]2	1[illegible]
1/1[illegible]/53	31.[illegible]	1[illegible]		
1/19/53	31.[illegible]	153	0.[illegible]	104
1/23/53	32.[illegible]	1[illegible]7	0.[illegible]3	115
1/2[illegible]/53	31.[illegible]	141	0.5[illegible]	[illegible]3
[illegible]/30/53	3[illegible]	142	0.[illegible]3	[illegible]
2/2/53	[illegible]	[illegible]	0.[illegible]	[illegible]
2/[illegible]/53	32.[illegible]	1[illegible]2	0.[illegible]1	
2/[illegible]/53	3[illegible]	[illegible]	0.4	[illegible]
2/[illegible]/53	32.[illegible]	[illegible]1	0.42	5[illegible]
2/1[illegible]/53	32.[illegible]	121	[illegible].52	[illegible]3
2/1[illegible]/53	32.1	[illegible]	0.[illegible]5	[illegible]
[illegible]/[illegible]/53	33.[illegible]	[illegible]	0.5[illegible]	[illegible]
2/1[illegible]/53	3[illegible]	11[illegible]	0.[illegible]	
2/2[illegible]/53	36.[illegible]	[illegible]5	0.4[illegible]	4[illegible]
2/24/53	33.[illegible]	[illegible]2	0.[illegible]	
2/2[illegible]/53	34.[illegible]	[illegible]	0.[illegible]4	[illegible]

(Continued)

* Infiltrometer test (artificial rainfall).

(Sheet [illegible] of [illegible] sheets)

Table A3 (Continued)

Date	MC, %	CI	RI	RCI
Site 6, Vicksburg, Miss. (Cont'd)				
3/2/53	34.1	112	0.55	62
3/5/53	33.7	89	0.34	30
3/5/53	32.9	95	0.57	54
3/9/53	32.7	129	0.55	71
3/12/53	34.0	89		
3/16/53	34.2	88	0.66	60
3/19/53	34.2	91	0.59	54
3/23/53	34.6	95	0.40	38
3/23/53	33.9	101	0.58	59
3/26/53	33.6	90	0.52	47
3/30/53	32.7	99	0.62	61
4/2/53	32.0	121	0.59	71
Site 7, Vicksburg, Miss.				
4/8/52	29.9	150	0.24	36
4/15/52	30.5	152	0.31	47
4/22/52	27.9	180	0.24	43
4/29/52	30.4	177	0.29	51
5/6/52	24.6	235		
5/20/52	25.[illegible]	254		
5/27/52	27.5	171	0.38	[illegible]5
6/3/52	25.2	186		
7/18/52*	28.1	146		
12/5/52	31.8	152	0.40	61
12/8/52	30.3	166	0.29	48
12/12/52	29.3	181	0.32	58
12/15/52	27.5	185		
12/19/52	28.5	209	0.47	98
12/22/52	27.9	124	0.42	52
12/29/52	29.7	179	0.33	59
1/2/53	30.9	127	0.66	84
1/5/53	29.1	179	0.41	73
1/9/53	30.8	138	0.48	66
1/12/53	30.9	173	0.43	74
1/16/53	29.6	195		
1/19/53	27.9	134	0.78	104
1/23/53	30.9	106	0.40	42
1/26/53	29.5	118		
1/30/53	32.3	147	0.27	40
2/2/53	29.9	160		
2/6/53	30.0	105	0.96	101
2/9/53	30.9	139	0.39	54
2/12/53	28.6	103	0.30	31
2/13/53	29.2	122	0.59	72
2/16/53	29.7	123	0.48	59
2/17/53	28.9	148	0.38	56
2/19/53	28.6	141	0.78	110
2/21/53	31.3	106	0.38	40
2/26/53	30.2	83	0.63	52
2/27/53	29.2	120	0.20	24
3/2/53	29.5	121	0.45	54
3/5/53	27.1	131	0.69	90
3/6/53	28.0	127	0.32	41
3/9/53	29.1	180	0.43	77
3/9/53	27.6	166	0.30	50
3/12/53	33.0	111	0.57	63
3/16/53	31.6	98	0.41	40
3/19/53	29.6	110	0.46	51
3/23/53	31.3	111	0.45	50
3/26/53	29.7	121	0.40	48
3/26/53	27.5	110	0.16	18
3/30/53	26.2	153	0.52	80
3/30/53	30.0	125	0.45	56
3/31/53	29.0	151	0.60	91
4/2/53	31.5	146	0.35	51
Site 8, Vicksburg, Miss.				
4/8/52	23.4	266		
4/15/52	26.8	189	0.67	127
4/22/52	23.7	248		
4/29/52	25.0	234	0.74	173
Site 8, Vicksburg, Miss. (Cont'd)				
5/27/52	24.1	214		
6/3/52	25.0	225		
11/28/52	27.1	168		
12/5/52	28.4	162	0.89	144
12/8/52	26.7	196	0.83	163
12/12/52	27.5	199	0.81	161
12/15/52	25.3	270		
12/19/52	25.4	237		
12/22/52	29.2	166	0.95	158
12/29/52	27.1	222		
1/2/53	29.5	153		
1/5/53	27.1	188		
1/9/53	31.1	110		
1/12/53	29.1	198		
1/16/53	27.7	213		
1/19/53	28.3	167		
1/23/53	30.5	154	0.79	122
1/26/53	29.2	136		
1/30/53	30.7	156		
2/2/53	27.1	221		
2/6/53	2[illegible].0	204		
2/9/53	27.7	172		
2/13/53	27.1	202	0.84	170
2/13/53	28.8	119	0.88	105
2/16/53	26.8	187	0.70	131
2/17/53	27.8	173	0.80	138
2/19/53	28.3	150		
2/24/53	28.8	148	0.70	104
2/26/53	27.2	168		
3/2/53	27.9	164		
3/5/53	27.3	171	0.79	135
3/5/53	26.5	188		
3/9/53	26.4	198		
3/12/53	27.5	142		
3/16/53	29.7	13[illegible]	0.81	110
3/17/53	28.[illegible]	122	0.[illegible]5	79
3/19/53	27.4	188		
3/23/53	28.7	155	0.91	141
3/26/53	27.1	158		
3/30/53	27.2	186		
4/2/53	25.3	214		
Site 9, Ellisville, Miss.				
7/12/52*	18.4	233		
7/15/52*	16.8	252		
7/17/52*	15.8	300		
7/18/52*	16.9	267		
1/15/53	19.0	272	0.52	141
1/22/53	20.7	258	0.44	114
1/28/53	17.6	270		
2/5/53	18.7	252		
2/11/53	18.4	266	0.89	237
2/18/53	18.3	277		
2/27/53	17.2	259		
3/11/53	20.1	249	0.30	75
3/19/53	18.0	24[illegible]		
3/24/53	20.2	284	0.42	119
3/30/53	16.7	300		
Site 10, Ellisville, Miss.				
7/12/52*	19.9	160	0.7[illegible]	122
7/1[illegible]/52*	17.8	300		
7/18/52*	17.5	300		
1/15/53	24.0	131	0.39	51
1/22/53	25.0	124	0.48	[illegible]0
2/5/53	25.2	157	0.38	[illegible]0
2/11/53	25.4	133	0.38	50
2/18/53	25.7	123	0.35	43
2/27/53	23.4	144	0.30	43
3/4/53	24.8	132	0.37	49
3/11/53	24.2	1[illegible]4	0.20	33
Site 10, Ellisville, Miss. (Cont'd)				
3/13/53	26.1	142	0.34	48
3/19/53	22.4	177	0.29	51
3/23/53	23.1	173	0.33	57
3/30/53	25.3	151	0.25	38
Site 12, Laurel, Miss.				
7/12/52*	23.0	126	0.80	101
7/14/52*	21.6	175	0.76	133
7/14/52*	18.8	228		
7/15/52*	19.5	165	1.39	229
7/16/52*	20.6	165	0.64	106
7/16/52*	17.2	250		
7/17/52*	20.6	165	0.87	144
7/17/52*	18.0	237		
7/18/52*	18.0	204		
1/13/53	25.2	109	0.51	56
1/20/53	25.3	108	0.74	80
1/27/53	25.8	117	0.62	72
2/3/53	26.[illegible]	93	0.78	72
2/10/53	26.6	89	0.83	74
2/20/53	26.6	109	0.61	66
2/25/53	27.9	105	0.72	76
3/4/53	25.9	103	0.80	82
3/11/53	26.9	113	0.55	62
3/12/53	28.[illegible]	104	0.51	53
3/18/53	27.5	110	0.76	84
3/25/53	26.9	106	0.68	72
3/30/53	24.7	107	0.68	73
Site 13, Eddins, Miss.				
7/14/52*	38.5	161		
7/15/52*	37.4	199	1.06	211
7/16/52*	30.5	300		
7/17/52*	32.0	300		
7/18/52*	33.9	300		
1/14/53	43.6	136	1.06	144
1/21/53	38.7	129	1.12	144
1/27/53	44.0	125		
2/10/53	40.8	109	1.07	117
2/13/53	40.8	114	1.04	1[illegible]
2/26/53	42.2	78	0.93	72
3/5/53	41.3	100	0.98	98
3/9/53	40.1	110	1.09	120
3/12/53	41.0	85	0.88	75
3/16/53	37.2	91	1.18	107
3/20/53	44.4	116	0.96	111
3/26/53	40.5	89	1.04	93
3/30/53	40.9	140	1.36	190
Site 14, Lafayette, Ind.				
12/6/51	24.9	179	0.62	111
12/11/51	24.6	168		
1/3/52	26.0	142		
1/8/52	24.0	146		
1/15/52	25.7	165		
1/22/52	27.2	155		
2/5/52	26.4	129		
2/13/52	26.9	143		
2/21/52	26.4	166		
2/27/52	23.5	188		
3/5/52	28.1	149		
3/12/52	26.3	123		
3/19/52	26.7	145		
3/26/52	25.4	146		
4/2/52	25.0	200		
4/7/52	25.3	139		
4/24/52	27.4	127		
4/28/52	24.7	187		
5/5/52	24.5	159		
5/12/52	26.7	110		

(Continued)

* Trafficability tests (artificial rainfall).

Table A3 (Continued)

Date	MC, %	CI	RI	RCI
Site 14, Lafayette, Ind. (Cont'd)				
5/19/52	27.1	98		
5/28/52	31.1	101	0.44	44
6/4/52	24.5	136		
6/11/52	21.8	199		
6/16/52	25.2	109		
6/25/52	25.4	140		
7/2/52	20.0	248		
7/23/52	18.3	300		
8/14/52	23.1	229		
8/20/52	23.5	168		
8/27/52	21.7	230		
9/3/52	19.8	246		
9/10/52	20.0	265		
9/17/52	18.7	279		
9/25/52	23.1	213		
9/30/52	20.7	274		
10/7/52	20.0	268		
10/14/52	19.1	263		
10/21/52	23.7	211		
10/28/52	21.2	232		
11/4/52	23.8	224		
11/12/52	22.8	220		
11/19/52	25.7	150		
11/26/52	28.0	130		
12/3/52	25.4	149		
12/10/52	25.4	131		
12/17/52	26.5	147		
12/22/52	25.4	139		
12/29/52	23.2	163		
1/5/53	24.1	178		
1/12/53	27.1	132		
1/19/53	25.7	150		
1/26/53	26.8	132		
2/4/53	27.5	136		
2/12/53	26.3	157		
2/17/53	25.7	136		
2/26/53	26.4	123		
3/5/53	28.4	125		
3/13/53	26.8	109	0.55	60
3/19/53	30.4	120	0.40	48
3/26/53	26.5	109	0.60	65
4/2/53	28.3	122		
4/8/53	29.0	119	0.61	73
4/16/53	27.5	100		
4/23/53	27.0	139	0.72	100
4/30/53	25.4	145		
5/7/53	26.8	177	0.69	122
5/14/53	24.4	155		
Site 15, Lafayette, Ind.				
4/17/52	29.1	115		
4/21/52	34.5	102		
4/30/52	32.9	123		
5/5/52	34.2	135		
5/12/52	35.2	108		
5/21/52	35.6	102		
5/26/52	37.5	91		
6/4/52	32.4	121		
6/11/52	29.2	148		
6/18/52	31.6	112		
6/25/52	32.5	103		
7/2/52	30.1	162		
7/9/52	29.7	192		
7/23/52	24.1	279		
9/3/52	27.3	204		
9/10/52	24.4	242		
9/17/52	24.5	263		
9/26/52	28.2	188		
9/30/52	30.7	197		
10/7/52	27.8	203		
10/14/52	24.8	233		
10/21/52	28.2	191		
Site 15, Lafayette, Ind. (Cont'd)				
10/28/52	28.0	184		
11/4/52	28.5	203		
11/12/52	27.8	216		
11/19/52	31.4	163		
11/26/52	34.4	142		
12/3/52	34.1	115		
12/10/52	34.9	107		
12/17/52	33.6	157		
12/22/52	37.1	103		
12/29/52	32.4	131		
1/5/53	32.4	136		
1/12/53	35.3	153		
1/19/53	35.0	144		
1/26/53	34.3	111		
2/4/53	33.8	145		
2/12/53	34.3	135		
2/17/53	34.5	122		
2/26/53	35.9	112		
3/5/53	32.9	119		
3/13/53	33.9	94		
3/18/53	31.3	102		
3/26/53	35.5	138		
4/2/53	34.7	131		
4/8/53	35.4	101		
4/16/53	34.3	90		
4/23/53	35.0	143		
4/30/53	33.2	133		
5/7/53	33.4	108		
5/14/53	30.2	122		
Site 16, Lafayette, Ind.				
6/5/52	29.5	92		
6/12/52	29.9	84		
6/18/52	29.5	92		
6/23/52	30.5	93		
6/30/52	25.2	155		
7/7/52	19.7	300		
8/13/52	19.6	297		
8/18/52	27.0	131		
8/25/52	22.4	161		
9/3/52	22.0	198		
9/8/52	23.0	236		
9/23/52	26.5	149		
10/1/52	24.7	194		
10/10/52	21.3	254		
10/15/52	25.7	192		
10/23/52	23.2	220		
10/29/52	26.0	181		
11/5/52	23.7	233		
11/10/52	23.6	193		
11/17/52	22.6	202		
11/24/52	27.7	134		
12/1/52	28.5	135		
12/8/52	28.4	130		
12/15/52	28.8	152		
12/20/52	29.2	102		
12/31/52	27.7	115		
1/7/53	29.0	142		
1/14/53	29.2	136		
1/21/53	29.1	130		
1/27/53	28.5	114		
2/2/53	29.0	128		
2/9/53	28.5	148		
2/16/53	28.1	191		
/23/53	29.3	122		
3/2/53	28.8	143		
3/9/53	29.6	129		
3/16/53	30.3	108	0.65	70
3/23/53	29.9	113		
/30/53	28.4	117		
4/7/53	28.4	110		
4/13/53	26.6	139		
Site 16, Lafayette, Ind. (Cont'd)				
4/20/53	29.1	132		
4/27/53	27.3	141	0.89	126
5/4/53	28.8	152		
5/11/53	28.9	133		
Site 17, Lafayette, Ind.				
12/6/51	119.5	101	0.32	32
12/13/51	96.6	115		
1/17/52	169.0	78		
1/24/52	106.3	98		
2/18/52	130.6	86		
2/25/52	132.1	114		
3/3/52	92.2	125		
4/21/52	75.5	96		
6/2/52	40.9	83		
6/12/52	71.8	80		
6/30/52	115.7	88		
7/7/52	63.3	89		
7/14/52	94.8	94		
7/21/52	89.9	79		
7/28/52	90.2	92		
8/4/52	144.2	101		
8/13/52	60.5	86		
8/18/52	69.4	81		
8/25/52	53.6	91		
9/3/52	49.6	120		
9/15/52	46.2	132		
9/23/52	54.0	103		
10/2/52	53.9	128		
10/8/52	44.4	150	1.01	152
10/16/52	51.7	115		
10/23/52	68.7	144		
10/29/52	50.3	151		
11/5/52	47.5	154		
11/10/52	73.6	138		
11/17/52	71.2	125		
11/24/52	85.5	95		
12/1/52	56.9	110		
12/8/52	66.1	125		
12/15/52	48.5	148		
12/31/52	43.0	132		
1/7/53	44.9	129		
1/14/53	49.1	138		
1/21/53	44.7	134		
1/27/53	47.4	129		
2/2/53	43.7	125		
2/9/53	49.2	142		
2/16/53	57.8	148		
2/23/53	52.5	114		
3/2/53	55.3	154		
3/9/53	58.4	111		
3/23/53	52.9	101		
4/7/53	56.4	126		
4/13/53	55.0	114		
4/20/53	62.6	133		
4/27/53	57.5	131		
5/4/53	50.5	130		
5/11/53	53.0	140		
Site 18, Lafayette, Ind.				
5/21/52	26.5	141		
5/26/52	25.5	103		
6/2/52	26.1	176		
6/11/52	23.6	273		
6/16/52	28.6	109		
6/23/52	29.5	132		
6/30/52	23.1	207		
7/14/52	18.2	300		
8/1[illegible]/52	18.2	283		
8/13/52	26.1	118		
8/25/52	24.0	145		

(Continued)

Table A3 (Continued)

Date	MC, %	CI	RI	RCI
Site 18, Lafayette, Ind. (Cont'd)				
9/3/52	24.1	199		
9/8/52	19.6	238		
9/15/52	20.2	284		
9/24/52	21.7	188		
10/1/52	21.7	236		
10/16/52	24.7	215		
10/24/52	23.5	204		
10/30/52	23.3	200		
11/6/52	26.1	175		
11/20/52	25.7	166		
11/28/52	28.0	127		
12/4/52	26.9	113		
12/11/52	28.8	146		
12/18/52	28.6	159		
12/30/52	28.5	159		
1/7/53	27.5	159		
1/15/53	30.0	143		
1/22/53	29.1	170		
1/28/53	28.3	151		
2/5/53	28.1	157		
2/11/53	29.0	142		
2/18/53	23.4	165		
2/25/53	28.9	149		
3/4/53	28.6	129		
3/11/53	28.9	136		
3/25/53	29.6	175		
4/1/53	28.9	137		
4/9/53	28.4	171		
4/15/53	28.5	169		
4/22/53	27.2	180	0.77	139
4/29/53	27.3	182		
5/6/53	25.7	225		
5/13/53	24.8	233		
Site 19, Lafayette, Ind.				
12/7/51	30.4	173		
12/13/51	29.8	174		
3/10/52	32.8	143		
6/30/52	30.6	150		
7/16/52	27.3	183		
7/23/52	27.2	214		
7/31/52	21.2	300		
8/6/52	21.9	300		
8/14/52	27.7	164		
8/20/52	24.3	197		
8/27/52	25.3	237		
9/3/52	27.0	243		
9/10/52	24.4	255		
9/17/52	25.0	300		
9/24/52	25.3	200		
10/2/52	26.3	215		
10/8/52	25.8	252		
10/16/52	29.2	187		
10/30/52	23.9	193		
11/6/52	27.8	212		
11/13/52	26.4	202		
Site 20, Brazil, Ind.				
12/5/51	28.8	156		
12/12/51	24.8	188	0.46	86
1/2/52	25.6	132	0.42	55
1/10/52	26.2	179	0.40	72
1/16/52	27.4	145	0.50	72
1/23/52	25.6	165		
2/7/52	27.5	126	0.40	50
2/12/52	24.9	178	0.48	85
2/19/52	25.4	205	0.45	92
2/26/52	24.9	202	0.61	123
3/4/52	30.3	125		
3/11/52	26.7	167	0.48	80
3/18/52	27.0	113		
3/25/52	27.2	135	0.43	58
Site 20, Brazil, Ind. (Cont'd)				
4/3/52	25.9	158	0.52	82
4/8/52	26.7	153	0.42	64
4/15/52	27.3	98	0.42	41
4/25/52	26.1	169		
4/29/52	24.7	224		
5/8/52	22.1	280		
5/13/52	22.1	300		
5/23/52	21.8	300		
5/27/52	23.0	227		
6/24/52	24.9	256		
8/19/52	22.1	286		
9/2/52	20.8	283		
10/25/52	20.9	285		
12/4/52	24.6	161	0.61	98
12/11/52	25.2	142		
12/18/52	24.7	197		
12/23/52	25.2	170		
12/30/52	23.5	182		
1/8/53	24.6	149		
1/15/53	24.8	166		
1/22/53	24.4	164		
1/29/53	24.8	180	0.46	83
2/12/53	25.2	156		
2/19/53	25.4	184	0.55	101
2/24/53	24.6	190		
3/3/53	26.3	138		
3/10/53	25.3	145	0.52	75
3/17/53	27.0	135	0.44	59
3/24/53	26.0	108		
3/31/53	26.1	103	0.36	37
4/6/53	29.1	101		
4/14/53	27.3	138	0.59	81
4/21/53	25.5	157		
4/28/53	25.3	172	0.37	64
5/5/53	24.8	168		
5/12/53	23.4	292		
Site 21, Attica, Ind.				
12/5/51	25.2	229		
12/12/51	24.1	225		
1/2/52	27.6	172		
1/10/52	26.4	217		
1/16/52	24.9	240		
1/23/52	25.4	214		
2/7/52	28.4	149		
2/12/52	24.8	164		
2/19/52	25.0	214		
2/26/52	24.6	231		
3/4/52	26.1	178		
3/11/52	27.1	143	0.49	70
3/18/52	25.3	159		
3/25/52	26.3	171		
4/3/52	23.2	230		
4/8/52	25.3	201		
4/15/52	26.0	133		
4/25/52	25.0	136		
5/23/52	21.6	285		
8/19/52	21.0	300		
11/20/52	23.7	276		
11/25/52	26.3	234		
12/4/52	23.9	202		
12/11/52	24.0	267		
12/18/52	23.6	266		
12/23/52	24.4	205		
12/30/52	23.3	283		
1/8/53	25.3	210		
1/15/53	23.9	229		
1/22/53	24.2	251		
1/29/53	25.0	233		
2/12/53	25.1	215		
2/19/53	24.7	268		
2/24/53	24.9	244		
Site 21, Attica, Ind. (Con't)				
3/10/53	25.5	242		
3/17/53	26.1	171		
3/24/53	26.0	152	0.40	61
3/31/53	28.2	174		
4/6/53	26.2	197	0.36	71
4/14/53	23.0	285		
4/21/53	23.0	273		
4/28/53	24.1	300		
5/5/53	22.9	300		
Site 22, Rapid City, S. Dak.				
3/29/52	13.6	174	1.60	278
4/5/52	15.2	172	1.10	189
4/12/52	13.5	174		
4/19/52	16.1	191		
4/25/52	13.8	161		
5/17/52	12.4	227		
5/31/52	23.7	89	0.86	76
6/9/52	21.4	114	0.38	43
6/16/52	15.9	142		
6/23/52	13.2	190		
6/30/52	19.0	125		
7/7/52	14.1	172		
7/14/52	19.0	134		
7/21/52	14.1	185		
7/28/52	10.9	244		
Site 23, Rapid City, S. Dak.				
3/1/52	20.4	300		
3/29/52	24.4	122		
4/5/52	27.7	158		
4/12/52	26.2	137		
4/19/52	26.7	181		
4/26/52	23.5	186		
5/3/52	21.4	268		
5/17/52	21.9	251		
5/23/52	30.7	98		
5/31/52	28.4	131		
6/9/52	23.1	195		
6/16/52	20.2	300		
6/30/52	24.2	107		
7/7/52	23.5	227		
7/14/52	27.5	105		
7/21/52	25.2	228		
Site 24, Rapid City, S. Dak.				
4/5/52	21.7	221		
4/12/52	21.9	253		
4/19/52	20.2	265		
5/24/52	22.8	157	0.74	116
5/31/52	21.2	240		
6/30/52	20.5	228		
Site 25, Rapid City, S. Dak.				
3/29/52	16.6	206		
4/5/52	16.8	175		
4/12/52	16.8	170		
4/19/52	17.2	171		
4/26/52	15.3	200		
5/3/52	11.3	208		
5/10/52	10.5	249		
5/17/52	16.4	186		
5/24/52	23.7	120	0.72	86
5/31/52	21.5	136	0.86	117
6/9/52	21.5	158		
6/16/52	16.1	146		
6/23/52	14.2	205		
6/30/52	19.5	160		
7/7/52	17.1	170		

(Continued)

Table A3 (Continued)

Site 25, Rapid City, S. Dak. (Cont'd)

Date	MC, %	CI	RI	RCI
7/14/52	17.9	167		
7/21/52	13.5	204		
7/28/52	10.2	255		

Site 26, Lincoln, Nebr.

Date	MC, %	CI	RI	RCI
2/9/52	29.0	213	0.68	145
2/16/52	32.1	148	0.67	99
2/23/52	31.4	174		
3/1/52	31.5	158		
3/8/52	33.1	203		
3/15/52	34.6	147		
3/29/52	30.9	133		
4/5/52	33.1	152		
4/12/52	35.4	102		
4/19/52	34.3	109	0.67	73
4/26/52	34.7	109	0.75	82
5/3/52	30.6	141	0.72	102
5/10/52	25.5	244		
5/17/52	28.4	182	0.84	153
5/24/52	30.3	134	0.71	95
5/31/52	29.2	179	0.68	122
6/21/52	28.7	201	0.86	173
6/28/52	31.2	134	0.78	104
7/5/52	25.2	208		
7/19/52	29.9	159	0.80	127
11/29/52	24.3	300		
12/6/52	26.3	248		
12/13/52	30.5	170	0.83	141
12/22/52	31.6	112	0.76	85
12/23/52	31.9	120	0.71	85

Site 27, Lincoln, Nebr.

Date	MC, %	CI	RI	RCI
2/16/52	28.2	208		
2/23/52	26.7	269		
3/1/52	28.7	221		
3/8/52	24.0	263		
3/15/52	29.6	173		
3/29/52	31.3	152		
4/4/52	27.1	189		
4/12/52	32.8	72		
4/19/52	29.9	144	0.54	78
4/26/52	29.5	131	0.55	72
5/3/52	27.6	157	0.57	90
5/10/52	25.0	267	0.90	240
5/17/52	23.9	194		
5/24/52	22.7	238	0.68	162
5/31/52	23.5	225		
12/13/52	25.2	177	0.82	145

Site 28, Lincoln, Nebr.

Date	MC, %	CI	RI	RCI
2/9/52	23.0	283		
2/16/52	23.4	272		
2/23/52	24.2	177		
3/1/52	27.9	180		
3/8/52	23.8	259		
3/15/52	24.9	200		
3/29/52	26.1	145		
4/5/52	24.7	139		
4/12/52	26.7	140		
4/19/52	25.7	114		
4/26/52	25.8	144	0.81	117
5/3/52	23.9	147	0.82	120
5/10/52	23.0	239	0.90	215
5/17/52	24.9	128	0.78	100
5/24/52	25.6	153	0.73	112
5/31/52	23.8	155	0.97	150
6/28/52	22.1	175	0.90	158
7/5/52	21.0	300	0.92	276
7/26/52	20.6	300	0.83	249

Site 28, Lincoln, Nebr. (Cont'd)

Date	MC, %	CI	RI	RCI
11/17/52	22.2	239		
12/13/52	22.7	226		

Site 29, Valparaiso, Nebr.

Date	MC, %	CI	RI	RCI
2/16/52	26.4	213		
2/23/52	30.2	75		
3/1/52	33.0	130	0.93	121
3/8/52	27.3	150		
3/15/52	30.2	156		
3/29/52	32.2	114		
4/5/52	32.2	121		
4/12/52	34.0	59		
4/19/52	30.7	109		
4/26/52	32.6	84	0.68	57
5/3/52	30.0	100	0.94	94
5/10/52	28.7	151	0.84	127
5/17/52	26.8	159		
5/24/52	29.9	117	0.71	83
5/31/52	27.0	174	0.86	150
6/7/52	24.5	175		
6/21/52	17.0	286	0.67	192
6/28/52	28.3	120	0.83	100
7/5/52	25.4	163	0.82	134
7/12/52	20.6	251		
7/19/52	20.4	208	0.77	160
8/16/52	18.6	249	0.83	207
8/30/52	20.2	232		
11/17/52	17.5	300		

Site 30, Columbia, S. C.

Date	MC, %	CI	RI	RCI
12/29/51	30.2	169	0.74	125
1/4/52	29.0	193	[illegible]	114
1/11/52	30.0	163	0.68	111
1/18/52	29.6	176	0.82	144
1/25/52	28.5	171	0.67	115
2/1/52	32.4	170	0.70	119
2/8/52	30.0	178	0.93	166
2/15/52	30.6	154	0.83	128
2/21/52	29.8	167	0.84	140
2/26/52	32.9	177	0.73	129
3/4/52	31.8	133	0.64	85
3/19/52	33.2	121	0.82	99
3/31/52	36.0	95	0.68	65
4/7/52	35.6	121	0.71	86
4/14/52	31.2	151	0.82	124
4/22/52	28.0	225	0.85	191
4/28/52	30.2	165	0.76	125
5/5/52	31.5	195	1.01	197
5/15/52	28.0	212		
5/20/52	29.4	168	0.80	134
5/25/52	28.9	185	0.94	174
6/3/52	25.7	193	0.89	172
6/10/52	23.6	235		
6/17/52	22.3	300		
6/24/52	24.3	221	0.87	192
7/1/52	23.5	296		
7/15/52	22.3	270		
8/5/52	24.0	272	0.76	207
8/12/52	25.7	218	0.65	142
8/19/52	20.3	292		
9/2/52	28.4	216	0.74	160
9/9/52	25.1	221	0.84	186
9/22/52	26.7	172	0.61	105
9/29/52	23.8	254	0.78	198
10/6/52	22.7	300+	1.07	321+
10/13/52	22.4	256	0.62	159
10/21/52	20.5	291		
10/28/52	22.0	289		
11/18/52	21.1	283		
11/25/52	25.5	251	0.80	201
12/3/52	25.5	238	0.65	155

Site 30, Columbia, S. C. (Cont'd)

Date	MC, %	CI	RI	RCI
12/8/52	27.0	220	0.67	147
12/16/52	23.7	259	0.76	197
12/17/52	24.5	237	1.20	284
12/18/52	25.3	248		
12/19/52	24.3	278	0.90	250
12/23/52	26.1	219	0.72	158
12/30/52	24.4	254	0.63	160

Site 31, Columbia, S. C.

Date	MC, %	CI	RI	RCI
12/28/51	28.5	156	0.72	112
1/7/52	27.7	150	0.70	105
1/14/52	28.0	176	0.76	134
1/23/52	28.2	148	0.69	102
1/29/52	29.5	158	0.72	114
2/5/52	30.6	174	0.60	104
2/12/52	28.1	160	0.74	118
2/18/52	29.5	159		
2/25/52	28.0	165	0.69	114
3/12/52	31.8	158	0.82	130
3/20/52	31.0	151	0.73	110
4/4/52	28.9	146	0.74	108
4/7/52	27.3	161	0.74	119
4/14/52	27.9	178	0.76	135
4/21/52	26.7	212	0.94	199
4/28/52	28.5	164	0.67	110
5/6/52	25.5	222		
5/13/52	24.0	215	0.95	204
5/19/52	23.8	281		
5/28/52	27.0	191	0.78	149
6/3/52	24.1	267	1.06	283
6/10/52	26.8	226	0.94	212
6/17/52	25.5	197	0.74	146
6/24/52	26.0	182	0.82	149
7/1/52	23.4	251	0.64	161
7/15/52	22.3	300		
8/5/52	24.2	126	0.75	94
8/12/52	26.2	145	0.68	99
8/19/52	26.7	136	0.87	118
8/26/52	25.3	165	0.89	147
9/3/52	25.6	132	0.77	102
9/10/52	23.7	189	1.07	202
9/24/52	24.5	136	0.82	112
10/10/52	22.5	202	0.72	145
10/15/52	22.9	206	0.53	109
10/22/52	22.7	227		
11/26/52	24.7	177	0.93	165
12/3/52	25.1	166	0.73	121
12/10/52	25.4	146	0.73	107
12/16/52	24.1	158		
12/17/52	22.8	144	0.83	120
12/18/52	25.9	192	0.87	167
12/19/52	24.5	154	1.02	157
12/23/52	24.5	141	0.55	78
12/30/52	27.4	145	0.59	86

Site 32, Columbia, S. C.

Date	MC, %	CI	RI	RCI
12/28/51	31.2	195		
1/9/52	28.4	202		
1/16/52	32.0	163		
1/23/52	35.6	181		
1/29/52	28.5	178	0.67	119
2/11/52	32.2	197		
2/19/52	32.4	190		
2/27/52	28.0	178		
3/7/52	31.6	184		
3/12/52	29.6	190		
3/21/52	30.3	181		
3/26/52	28.4	191		
4/4/52	33.7	190		
4/9/52	29.6	205		
4/18/52	26.7	291		

(Continued)

Table A3 (Continued)

Site 32, Columbia, S. C. (Cont'd)

Date	MC, %	CI	RI	RCI
4/22/52	30.1	280		
4/29/52	36.9	196		
5/6/52	28.6	254		
5/17/52	27.6	300		
5/30/52	29.5	202		
6/4/52	29.1	246		
6/11/52	30.8	199		
6/24/52	27.5	300		
8/6/52	29.9	289		
8/13/52	31.6	174		
8/27/52	27.4	221		
9/3/52	35.4	206		
9/10/52	26.4	272		
9/17/52	26.8	244		
9/23/52	30.3	179		
10/10/52	26.5	255		
10/15/52	26.2	274		
10/22/52	26.4	300+		
10/29/52	26.5	300+		
12/3/52	29.9	258		
12/11/52	29.4	228		
12/17/52	30.5	230		
12/18/52	26.2	240		
12/19/52	27.5	228		
12/23/52	28.1	217	0.68	148

Site 33, Columbia, S. C.

Date	MC, %	CI	RI	RCI
2/22/52	26.7	160		
3/7/52	26.4	128		
3/14/52	26.6	139	0.49	68
3/22/52	27.1	172		
3/28/52	30.0	138		
4/4/52	25.7	149		
4/9/52	25.1	144		
4/18/52	26.5	192		
4/25/52	29.1	155		
4/29/52	27.0	166		
5/9/52	22.3	245		
5/23/52	20.2	280		
5/30/52	27.0	141	0.90	127
6/4/52	23.6	173		
6/12/52	27.1	151		
6/18/52	24.5	195		
6/25/52	20.2	235		
8/6/52	20.9	203		
8/13/52	24.8	143		
8/20/52	26.5	146		
8/27/52	21.1	189		
9/3/52	27.2	160		
9/10/52	21.6	230		
9/17/52	21.3	181		
9/23/52	24.5	142		
9/29/52	20.4	172	0.94	162
10/6/52	22.8	286		
10/15/52	22.2	235		
10/21/52	21.6	291		
10/28/52	20.5	300		
11/4/52	21.3	300		
11/12/52	21.6	300		
11/25/52	22.7	293		
12/3/52	21.2	300		
12/11/52	23.0	223		
12/16/52	18.7	223		
12/17/52	20.5	227		
12/18/52	20.4	215		
12/19/52	18.8	231		
12/23/52	20.0	176	0.75	132
12/30/52	22.6	223		
1/10/53	29.8	147		
1/16/53	26.9	155		
1/21/53	22.4	190		
1/29/53	26.5	120		

Site 33, Columbia, S. C. (Cont'd)

Date	MC, %	CI	RI	RCI
2/6/53	23.2	122		
2/13/53	24.6	116		
2/19/53	26.5	122		
2/27/53	30.7	99		

Site 34, Carlisle, S. C.

Date	MC, %	CI	RI	RCI
12/28/51	43.9	76	1.59	121
1/2/52	41.6	77	1.11	86
1/9/52	39.0	87		
1/16/52	43.3	62	2.01	125
1/24/52	39.6	82	1.14	94
1/30/52	46.0	81	0.76	62
2/6/52	38.7	90		
2/13/52	40.7	85		
2/20/52	45.4	96		
2/29/52	44.2	73		
3/5/52	47.4	65		
3/11/52	44.7	75	1.09	82
3/19/52	43.3	70	1.99	139
3/25/52	46.6	73	1.71	125
4/2/52	41.8	83	0.96	80
4/8/52	37.1	139	1.18	164
4/16/52	38.7	103	1.06	109
4/23/52	32.1	181		
4/30/52	35.5	173	1.17	202
5/14/52	40.2	188	0.99	186
5/28/52	45.5	88	1.07	94
6/2/52	42.9	121	1.22	148
6/9/52	37.9	134	1.15	154
6/16/52	38.5	188	1.25	235
6/23/52	34.7	240	1.09	262
6/30/52	33.0	300		
7/14/52	31.5	235	1.07	252
8/4/52	34.1	300	1.00	300
8/11/52	38.4	145	1.02	148
8/19/52	36.8	210	1.11	233
8/25/52	36.6	206	1.18	243
9/1/52	43.1	155	1.20	186
9/8/52	40.2	141	1.28	180
9/18/52	35.1	212		
9/26/52	38.4	160		
10/2/52	36.9	215	1.05	226
10/7/52	31.4	300		
10/14/52	37.0	228		
10/20/52	33.6	255		
10/27/52	31.5	273		
11/13/52	32.3	300		
11/17/52	31.8	300		
11/24/52	34.6	288		
12/9/52	37.1	203		
12/15/52	36.4	233		
12/16/52	40.1	259		
12/17/52	35.1	201		
12/23/52	38.3	193	1.20	232

Site 35, Columbia, S. C.

Date	MC, %	CI	RI	RCI
12/31/51	17.0	215		
1/14/52	17.9	243		
1/23/52	17.9	226	0.31	70
1/29/52	17.2	198	1.40	277
2/5/52	17.3	212	0.54	114
2/12/52	16.1	283	0.58	164
2/18/52	16.0	269		
2/25/52	17.2	288	0.80	230
3/7/52	18.0	275		
3/12/52	17.4	276	1.01	279
3/20/52	16.3	281	0.44	124
3/26/52	16.4	233	0.96	224
4/4/52	17.5	246	0.25	62
4/7/52	16.2	279		
4/29/52	16.2	202	0.62	125

Site 35, Columbia, S. C. (Cont'd)

Date	MC, %	CI	RI	RCI
6/4/52	15.1	286		
6/11/52	15.9	269		
8/6/52	16.0	266		
8/12/52	15.4	280	1.00	280
8/19/52	16.1	300	0.33	99
9/24/52	15.8	244		
11/26/52	16.1	278		
12/3/52	15.8	284		
12/16/52	18.9	274		
12/17/52	18.4	257	0.78	200
12/18/52	15.8	261		
12/19/52	17.2	264	0.83	219
12/23/52	17.1	262		

Site 38, Nacogdoches, Tex.

Date	MC, %	CI	RI	RCI
5/11/53	12.2	111		
6/1/53	10.1	143		
6/8/53	8.0	150		
6/15/53	8.0	160		
6/21/53	5.5	236		
7/6/53	8.5	164		
7/13/53	6.4	215		

Site 39, Poplar Bluff, Mo.

Date	MC, %	CI	RI	RCI
12/15/52	24.9	127		
12/22/52	23.4	101		
12/29/52	23.2	177		
1/5/53	23.8	123		
1/12/53	24.1	139		
1/19/53	27.3	88	0.61	54
1/26/53	24.9	106	0.58	62
2/2/53	24.0	105		
2/9/53	24.0	95		
2/16/53	25.3	99	0.70	69
2/23/53	28.8	83	0.58	48
3/2/53	28.5	65	0.57	37
3/9/53	26.5	72	0.60	43
3/16/53	27.1	62	0.61	38
3/23/53	27.0	60	0.60	36
4/2/53	25.5	95	0.62	59
4/7/53	28.3	77	0.59	45
4/13/53	27.9	73	0.66	48
4/20/53	29.4	81	0.59	48
4/27/53	22.8	79	0.67	53
5/4/53	24.5	97	0.62	60
5/12/53	27.7	81	0.61	49
5/18/53	27.6	66	0.63	42
5/25/53	20.7	97	0.61	59
6/1/53	20.0	186		

Site 41, Marianna, Fla.

Date	MC, %	CI	RI	RCI
8/18/54	3.6	277		
8/23/54	3.9	300		
8/27/54	5.8	188		
8/30/54	4.0	214		
8/31/54	5.0	207		
9/10/54	5.8	261		
9/17/54	5.9	185		
9/20/54	4.8	192		
9/22/54	6.2	216		
9/24/54	5.6	229		
9/27/54	6.6	191		
10/4/54	5.0	230		

Site 47, Union, S. C.

Date	MC, %	CI	RI	RCI
3/25/53	21.6	167	0.86	144
3/31/53	18.3	225	0.78	176
5/1/53	21.6	224	0.81	181
12/8/53	19.6	221	0.74	164

(Continued)

Table A3 (Continued)

Date	MC, %	CI	RI	RCI
Site 47, Union S. C. (Cont'd)				
12/10/53	23.1	197	0.74	146
1/25/54	22.4	187	0.59	110
Site 48, Union, S. C.				
3/25/53	27.5	193	0.89	172
3/31/53	26.1	249	0.90	224
5/1/53	24.4	263	0.84	221
12/8/53	23.0	281	0.78	219
12/10/53	22.5	221	0.71	157
1/25/54	24.9	214	0.82	175
Site 51, Glendora, Calif.				
4/8/53	15.7	93		
4/8/53	17.9	78		
4/14/53	16.6	82		
4/15/53	14.2	100		
4/21/53	17.4	103	3.04	313
4/21/53	15.4	85		
4/24/53	15.9	77	4.15	320
4/24/53	16.8	74		
4/28/53	18.7	68	1.67	114
4/28/53	17.1	82	2.69	221
4/30/53	18.6	61		
4/30/53	17.8	72		
5/4/53	16.6	111		
5/4/53	17.7	59		
6/1/53	13.0	123		
6/1/53	10.1	148		
6/8/53	12.3	87		
6/8/53	12.4	158		
6/15/53	12.5	107		
6/15/53	6.6	206		
6/22/53	13.1	154		
6/22/53	9.6	153		
7/1/53	7.7	181		
7/1/53	6.1	264		
7/5/53	7.0	222		
7/5/53	6.9	194		
7/12/53	6.7	212		
7/12/53	10.4	216		
7/19/53	4.6	284		
7/19/53	10.5	183		
7/26/53	5.0	280		
7/26/53	8.8	192		
8/2/53	9.6	143		
8/2/53	6.6	269		
8/9/53	8.7	269		
8/9/53	6.6	254		
Site 58, State College, Miss.				
3/5/53	30.1	136		
3/13/53	29.8	124	1.07	133
3/20/53	29.6	131	1.13	148
3/27/53	30.3	135	1.15	155
4/3/53	29.2	165	1.00	165
4/13/53	28.8	149	1.12	167
4/22/53	27.0	162	1.10	178
4/30/53	30.7	130	1.06	138
5/11/53	29.8	156	1.05	164
5/28/53	24.8	228	1.01	230
Site 60, Coshocton, Ohio				
2/24/53	23.2	136	0.59	80
3/11/53	24.7	136	0.59	80
3/12/53	25.4	97	0.67	65
3/15/53	24.5	158	0.71	112
3/16/53	23.8	156	0.73	114
3/17/53	23.3	142	0.68	97
3/19/53	24.6	148	0.59	87
3/20/53	21.9	147	0.64	94

Date	MC, %	CI	RI	RCI
Site 60, Coshocton, Ohio (Cont'd)				
3/22/53	22.4	171	0.77	132
3/24/53	25.3	134	0.60	80
3/28/53	23.9	116	0.61	71
4/2/53	24.1	136	0.72	98
4/22/53	23.2	133	0.70	93
4/24/53	24.7	207	0.64	132
5/7/53	22.2	142	0.61	87
5/8/53	24.7	161	0.43	69
Site 61, Coshocton, Ohio				
2/12/53	26.9	96	0.74	71
2/24/53	24.0	114	0.68	78
2/25/53	23.3	99	0.77	76
2/27/53	24.4	123	0.79	97
3/11/53	25.6	101	0.57	58
3/12/53	26.3	98	0.74	72
3/15/53	25.2	106	0.81	86
3/16/53	24.6	113	0.75	85
3/17/53	24.3	105	0.68	71
3/19/53	25.4	118	0.60	71
3/20/53	24.3	103	0.70	72
3/21/53	24.1	127	0.84	107
3/22/53	25.4	129	0.74	96
3/24/53	26.9	128	0.66	84
4/2/53	26.3	107	0.56	60
4/15/53	24.6	126	0.83	105
4/22/53	26.2	137	0.45	62
4/24/53	23.5	175	0.71	124
4/28/53	23.6	134	0.68	91
4/29/53	24.7	128	0.78	100
5/8/53	27.6	157	0.61	96
Site 62, East Lansing, Mich.				
3/22/53	22.0	192		
3/22/53	23.8	205		
3/27/53	18.9	181		
3/27/53	20.1	184		
4/3/53	18.1	188		
4/3/53	17.0	185		
4/11/53	19.1	202		
5/1/53	18.6	205		
5/15/53	16.3	215		
6/2/53	13.1	250		
6/17/53	10.5	261		
Site 67, Priest River, Idaho				
10/27/52	39.5	118	0.49	58
1/4/53	45.4	117	0.20	23
4/1/53	43.0	119	0.33	39
4/8/53	45.4	99	0.24	24
4/15/53	40.4	104	0.18	19
4/22/53	35.9	136	0.51	69
5/6/53	38.8	119	0.48	57
5/13/53	41.5	132	0.43	57
5/22/53	40.6	159	0.46	73
6/16/53	45.5	134	0.46	62
7/7/53	35.3	206	0.67	138
7/28/53	54.3	106	0.25	26
Site 71, Crossett, Ark.				
4/28/53	28.6	134	0.14	19
4/28/53	31.7	99	0.14	14
12/16/53	22.5	175	0.27	47
1/2/54	25.3	141	0.45	64
1/7/54	23.4	208	0.52	108
1/14/54	24.2	165	0.40	66
2/15/54	22.5	209	0.49	102
2/25/54	23.4	154	0.47	72
3/2/54	23.4	167	0.54	90
3/15/54	22.6	204	0.49	100

(Continued)

Date	MC, %	CI	RI	RCI
Site 72, Crossett, Ark.				
5/1/53	26.6	154	0.11	17
1/14/54	26.4	195	0.17	33
2/1/54	28.4	119	0.14	17
2/4/54	28.2	130	0.16	21
2/15/54	26.7	170	0.15	26
2/25/54	28.0	138	0.15	21
3/2/54	26.2	164	0.15	25
3/16/54	24.9	213	0.24	51
Site 74, Crossett, Ark.				
6/6/53	39.7	50		
11/24/53	25.1	186		
12/2/53	25.3	249		
12/14/53	28.6	132	0.40	53
12/21/53	27.2	136	0.36	49
1/7/54	29.7	97	0.38	37
1/14/54	32.8	63	0.38	24
2/1/54	32.6	101	0.44	44
2/15/54	29.9	113	0.48	54
2/25/54	33.2	65	0.34	22
3/4/54	32.8	136	0.38	52
3/17/54	31.4	102	0.41	42
Site 75, Crossett, Ark.				
5/7/53	20.9	239		
5/7/53	19.5	205		
12/21/53	17.2	229		
1/7/54	20.5	205		
1/14/54	25.2	158		
2/1/54	20.9	175		
2/4/54	20.1	115		
2/15/54	17.2	161		
2/25/54	20.5	226		
3/4/54	18.2	216		
3/16/54	18.1	300		
Site 76, Tijeras, N. Mex.				
10/27/53*	24.1	86	0.67	58
10/27/53*	26.3	101	0.74	75
10/29/53*	23.0	112	0.72	81
10/29/53*	24.2	96		
11/2/53*	20.8	138		
11/2/53*	22.7	132		
11/4/53*	19.9	143		
11/4/53*	22.3	186		
11/12/53	21.5	156		
11/12/53	23.3	164		
2/19/54	18.8	253		
2/23/54	20.2	182		
2/23/54	21.8	223	0.93	207
3/9/54	18.4	202		
3/11/54	18.7	178		
3/15/54	16.2	166		
3/19/54	17.6	205		
3/19/54	18.7	215		
Site 79, San Antonio, New Mexico				
7/7/53*	16.6	210		
7/7/53*	17.0	158		
7/7/53*	19.0	183		
7/7/53*	18.8	133		
7/9/53*	14.2	265		
7/9/53*	18.3	211		
7/9/53*	15.4	146		
7/9/53*	16.9	214		
7/13/53*	14.5	221		
7/13/53*	11.8	294		
7/13/53*	17.1	252		
7/13/53*	18.1	223		
7/14/53*	12.6	258		

* Infiltrometer test (artificial rainfall).

Table A3 (Continued)

Date	MC, %	CI	RI	RCI
Site 79, San Antonio, New Mexico (Cont'd)				
7/14/53*	20.4	153		
7/14/53*	11.4	299		
7/14/53*	16.6	242		
7/14/53*	20.6	185		
7/16/53*	14.5	242		
7/16/53*	18.7	182		
7/16/53*	14.0	253		
7/16/53*	19.1	170		
7/20/53	11.7	280		
7/20/53	16.8	227		
7/20/53	18.0	203		
7/20/53	14.1	273		
10/13/53*	15.2	259		
10/13/53*	19.6	203		
10/13/53*	22.2	153	0.86	132
10/13/53*	21.5	208		
10/13/53*	22.2	125	0.88	110
10/16/53*	21.1	157		
10/16/53*	21.1	222		
10/19/53*	20.6	250		
10/23/53	20.4	213		
10/29/53	18.4	191		
10/29/53	21.7	220		
11/4/53	18.8	249		
Site 81, Albuquerque, N. Mex.				
7/21/53*	12.4	207		
7/21/53*	15.7	224		
7/21/53*	16.4	124	0.70	87
7/21/53*	8.8	291		
7/21/53*	19.0	167	0.63	105
7/23/53*	12.5	241		
7/23/53*	13.7	216		
7/23/53*	13.6	190		
7/23/53*	9.2	286		
7/23/53*	13.8	180		
7/23/53*	14.2	204		
7/28/53*	10.8	246		
7/28/53*	14.4	250		
7/28/53*	18.3	151	0.72	109
7/28/53*	11.9	227		
7/28/53*	14.3	218		
7/28/53*	16.7	175	0.67	117
7/30/53*	9.6	283		
7/30/53*	13.1	280		
7/30/53*	14.2	205		
7/30/53*	10.3	277		
7/30/53*	12.6	269		
7/30/53*	14.5	206		
9/29/53*	9.6	269		
9/29/53*	12.3	235		
9/29/53*	17.0	149	0.90	134
9/29/53*	11.6	276		
9/29/53*	13.7	260		
9/29/53*	18.8	131	0.65	85
10/1/53*	12.9	274		
10/1/53*	15.9	201		
10/1/53*	12.6	250		
10/1/53*	13.7	216		
10/9/53*	12.6	263		
10/9/53*	12.6	275		
10/15/53*	10.6	292		
10/15/53*	11.4	294		
Site 83, Albuquerque, N. Mex.				
8/4/53*	25.9	153	0.76	116
8/4/53*	19.5	267		
8/4/53*	20.0	196		
8/4/53*	19.0	263		

Date	MC, %	CI	RI	RCI
Site 83, Albuquerque, N. Mex. (Cont'd)				
8/4/53*	23.9	174		
8/4/53*	28.6	138	0.86	119
8/4/53*	17.9	212		
8/4/53*	21.1	143	0.72	103
8/4/53*	23.3	132	0.77	102
8/4/53*	21.5	154	0.73	112
8/4/53*	17.6	157		
8/4/53*	22.7	155	0.76	118
8/6/53*	22.3	186		
8/6/53*	23.1	155	0.74	115
8/6/53*	24.3	168	0.92	155
8/6/53*	26.4	136	0.83	113
8/6/53*	24.8	169	0.84	142
8/6/53*	21.8	162	0.89	144
8/6/53*	21.2	162	0.80	130
8/6/53*	23.1	167	0.87	145
8/12/53*	21.5	150	0.84	126
8/12/53*	21.7	196		
10/7/53*	22.9	136	0.83	113
10/7/53*	21.4	117	0.78	91
10/7/53*	15.7	242		
10/7/53*	17.8	202		
10/7/53*	16.5	216		
10/14/53	19.5	184	0.84	155
10/14/53*	17.4	175	0.85	149
10/16/53*	18.8	172	0.85	146
10/16/53*	19.7	151		
10/22/53	25.0	171		
10/30/53	19.2	164		
10/30/53	20.1	153		
10/30/53	15.8	300		
11/3/53	14.6	300		
Site 85, Bernalillo, N. Mex.				
8/11/53*	18.4	125	0.76	95
8/11/53*	8.4	222		
8/11/53*	14.4	126		
8/11/53*	13.2	187		
8/11/53*	16.0	92		
8/11/53*	14.8	147	0.98	144
8/13/53	16.6	115		
8/13/53	14.7	171		
8/13/53	16.4	139		
8/13/53	14.8	143		
9/22/53*	14.3	199		
9/22/53*	9.6	288		
9/22/53*	19.0	101	0.97	98
9/22/53*	15.8	147		
9/22/53*	9.8	260		
9/22/53*	17.9	127	0.95	121
9/24/53*	15.6	117		
9/24/53*	14.0	138		
10/2/53*	12.8	164		
10/2/53*	12.0	227		
10/2/53*	13.5	190		
10/2/53*	12.2	220		
10/8/53*	11.5	217		
10/8/53*	11.7	188		
Site 88, Rhinelander, Wis.				
5/7/53	35.1	123	0.26	32
5/19/53	31.3	152	0.37	56
6/2/53	30.5	181	0.27	49
6/9/53	29.3	164	0.40	66
6/17/53	31.2	125	0.32	40
6/25/53	36.7	84	0.32	27
7/3/53	37.0	94	0.29	27
7/7/53	36.0	115	0.30	34
7/16/53	35.1	125	0.37	46

(Continued)

Date	MC, %	CI	RI	RCI
Site 88, Rhinelander, Wis. (Cont'd)				
7/21/53	23.2	201	0.39	78
7/30/53	36.1	146	0.41	60
8/4/53	36.4	136	0.29	38
8/26/53	20.7	266		
8/18/53	28.8	208	0.36	75
9/1/53	29.8	195		
9/9/53	27.6	203		
9/15/53	20.6	281		
9/22/53	18.1	277		
10/1/53	16.6	282		
10/22/53	15.1	300		
11/3/53	14.6	300		
Site 89, Rhinelander, Wis.				
5/7/53	30.5	169	0.48	81
5/19/53	25.7	184	0.40	74
6/2/53	25.9	200	0.53	106
6/9/53	21.6	222		
6/17/53	30.3	180	0.32	58
6/25/53	27.1	125	0.25	31
7/3/53	33.3	174	0.38	66
7/7/53	35.1	192	0.36	69
7/16/53	25.8	260		
7/23/53	17.2	269		
7/30/53	17.8	249		
8/11/53	21.4	277		
8/18/53	19.1	259		
8/26/53	11.3	279		
9/9/53	10.0	260		
Site 90, Rhinelander, Wis.				
5/7/53	22.2	199		
5/19/53	15.6	214		
6/4/53	22.4	200		
6/10/53	16.2	196		
7/3/53	25.7	133		
7/7/53	19.4	137		
7/16/53	18.5	181		
7/23/53	11.6	147		
7/30/53	12.1	163		
8/12/53	13.6	172		
8/18/53	15.5	217		
8/27/53	4.6	182		
9/2/53	7.7	182		
9/9/53	5.8	250		
9/15/53	6.1	178		
9/21/53	6.7	249		
9/30/53	6.5	228		
10/15/53	3.9	189		
10/21/53	4.6	287		
Site 91, Rhinelander, Wis.				
5/11/53	8.7	182		
5/19/53	9.6	189		
5/27/53	9.5	160		
6/10/53	6.4	212		
6/17/53	6.4	207		
6/23/53	9.1	217		
7/3/53	8.8	204		
7/7/53	11.8	145		
7/17/53	7.4	201		
7/22/53	5.6	201		
7/29/53	10.7	231		
8/5/53	13.6	93		
8/12/53	9.5	273		
8/19/53	9.6	231		
8/27/53	5.9	300		

* Infiltrometer test (artificial rainfall).

Table A3 (Continued)

Site 91, Rhinelander, Wis. (Cont'd)

Date	MC, %	CI	RI	RCI
9/2/53	7.1	216		
9/10/53	6.8	300		
9/16/53	4.3	292		
9/22/53	5.6	280		
9/30/53	6.4	300		
10/15/53	5.4	281		
10/21/53	7.5	288		
10/30/53	5.4	276		

Site 94, Rhinelander, Wis.

Date	MC, %	CI	RI	RCI
5/1/53	11.8	244		
6/2/53	9.9	221		
6/10/53	9.4	236		
6/19/53	19.0	189		
7/3/53	11.5	200		
7/15/53	12.0	264		
7/22/53	7.3	282		
7/29/53	13.3	224		
8/5/53	11.5	215		
8/13/53	10.7	216		
8/19/53	8.8	252		

Site 95, Rhinelander, Wis.

Date	MC, %	CI	RI	RCI
5/8/53	18.9	273		
5/20/53	20.7	279		
6/2/53	21.6	264		
6/10/53	18.9	300		
6/17/53	16.9	300		
6/23/53	19.2	266		
7/3/53	22.5	260		
7/9/53	17.0	275		
7/15/53	21.1	284		
7/22/53	20.1	300		
7/29/53	25.2	192	0.42	81
8/5/53	22.3	221	0.38	84
8/12/53	21.4	230		
8/19/53	18.4	300		
4/22/54	24.2	206	0.46	95
4/27/54	23.8	145	0.38	55
4/29/54	22.4	219	0.39	85

Site 96, Rhinelander, Wis.

Date	MC, %	CI	RI	RCI
5/5/53	21.1	200	0.29	58
6/17/53	26.3	210	0.39	82
6/25/53	29.6	99	0.28	28
7/3/53	30.1	108	0.29	31
7/9/53	29.8	192	0.44	84
7/17/53	18.6	239		
7/22/53	15.9	179		
7/29/53	23.8	118	0.61	72
8/5/53	22.7	132	0.33	44
8/12/53	15.2	245	0.38	93
8/19/53	20.3	247		
8/28/53	11.9	300		
9/7/53	14.4	293		
9/10/53	11.7	287		
9/16/53	9.7	300		
10/2/53	9.9	270		
10/8/53	11.3	300		
10/15/53	11.4	300		
10/21/53	10.4	300		

Site 97, Rhinelander, Wis.

Date	MC, %	CI	RI	RCI
5/8/53	29.1	143	0.35	50
5/20/53	28.4	132	0.38	50
6/4/53	25.3	162	0.38	62
6/10/53	23.9	207	0.31	64
6/17/53	27.9	179	0.30	54
6/25/53	28.7	104	0.23	24
7/2/53	32.8	98	0.30	29

Site 97, Rhinelander, Wis. (Cont'd)

Date	MC, %	CI	RI	RCI
7/9/53	25.8	177	0.37	66
7/17/53	20.6	220	0.26	57
7/24/53	13.3	229		
7/29/53	25.9	146	0.32	47
8/5/53	24.4	165	0.31	51
8/13/53	22.5	196		
8/19/53	18.4	225		
8/26/53	14.0	290		
9/3/53	13.3	275		
9/11/53	12.1	300		

Site 98, Rhinelander, Wis.

Date	MC, %	CI	RI	RCI
5/8/53	27.9	149	0.22	33
5/20/53	29.2	138	0.26	36
6/4/53	24.6	199	0.34	68
6/10/53	24.8	202	0.33	67
6/17/53	27.5	203	0.25	51
6/25/53	26.9	141	0.31	44
7/2/53	27.1	81	0.26	21
7/9/53	24.2	178	0.39	69
7/17/53	24.9	204	0.32	65
7/24/53	23.1	212		
7/29/53	29.4	123		
8/5/53	28.7	130	0.31	40
8/13/53	28.0	167	0.32	53
8/19/53	27.3	169	0.45	76
8/26/53	19.6	254		
9/3/53	21.4	246		
9/17/53	23.1	214		
9/23/53	16.3	268		
10/1/53	15.7	265		
10/8/53	13.9	294		
10/15/53	16.0	271		
11/3/53	12.5	299		

Site 101, Ashland, Wis.

Date	MC, %	CI	RI	RCI
5/15/53	26.1	143	1.05	150
5/29/53	29.8	107	0.88	94
6/12/53	25.3	126	0.97	122
6/26/53	20.3	159		
7/27/53	23.4	145	0.92	133
8/10/53	21.8	139	0.97	135
8/25/53	23.2	167	1.01	169
9/8/53	29.4	179		
4/14/54	27.8	143	1.00	143
4/23/54	24.2	137	1.02	140

Site 102, Ashland, Wis.

Date	MC, %	CI	RI	RCI
5/29/53	26.0	160	0.30	48
6/12/53	24.4	216	0.34	73
6/26/53	23.2	208	0.42	87
7/27/53	23.5	227	0.44	100
8/10/53	20.4	251		
8/26/53	17.2	294		
9/8/53	18.1	300		
2/10/54	16.6	224		
4/14/54	21.4	254	0.36	91
4/23/54	23.1	257	0.53	136
4/28/54	21.5	232	0.38	88

Site 103, Mesa Lake, Colo.

Date	MC, %	CI	RI	RCI
6/30/53	27.4	109	0.88	96
7/13/53	17.4	222		
8/10.53	13.8	127		
8/31/53	15.6	137		
9/7/53	16.6	122		
9/15/53	15.2	200		
10/20/53	26.0	99		
10/21/53	33.0	79	0.94	74
5/24/54	36.8	72	0.48	35
5/26/54	33.7	83	0.70	58

(Continued)

Site 103, Mesa Lake, Colo. (Cont'd)

Date	MC, %	CI	RI	RCI
5/28/54	32.0	81	0.95	77
5/31/54	33.4	96		

Site 105, Lands End, Colo.

Date	MC, %	CI	RI	RCI
6/19/53	31.9	159	0.92	146
6/29/53	27.2	79	0.95	75
7/13/53	21.2	224		
7/20/53	18.0	190		
8/3/53	18.5	242		
8/10/53	15.9	220		
8/31/53	15.5	300		
9/7/53	12.1	265		
9/14/53	13.7	300		
10/20/53	34.0	95	0.84	80
10/21/53	33.6	88	0.60	53
5/10/54	42.4	85	0.62	53
5/24/54	31.9	95	0.58	55
5/26/54	31.5	121	0.88	106
5/28/54	31.4	147	0.88	129
5/31/54	30.0	132		

Site 108, Mesa Lake, Colo.

Date	MC, %	CI	RI	RCI
6/29/53	72.6	161	0.42	68
7/2/53	70.4	136	0.62	84
8/4/53	61.9	157	0.84	132
8/31/53	62.5	151		
9/7/53	71.3	180	0.82	148
9/15/53	54.2	199	0.78	155
10/12/53	59.0	176	0.90	158

Site 109, Grand Mesa, Colo.

Date	MC, %	CI	RI	RCI
6/9/53	27.9	259		
6/30/53	23.9	300		
7/20/53	24.2	300		
8/4/53	30.2	220		
8/31/53	30.8	177		
9/7/53	29.6	161		
9/15/53	22.8	179		
10/28/53	20.9	258		
10/30/53	32.0	241		
5/10/54	33.3	92	0.78	72
5/13/54	32.6	101	0.80	81
5/25/54	29.4	161	0.89	143
5/31/54	27.6	158		

Site 110, Grand Mesa, Colo.

Date	MC, %	CI	RI	RCI
6/19/53	23.4	188		
6/30/53	19.6	164		
7/21/53	17.6	300		
8/4/53	22.0	129		
9/2/53	20.2	146		
9/7/53	16.7	216		
9/15/53	16.2	250		
11/2/53	32.6	117		
11/16/53	33.0	125		
4/19/54	32.5	104	0.72	75
4/22/54	31.8	113	0.72	81
4/27/54	33.4	81	0.60	49
5/6/54	32.2	96	0.72	69
5/10/54	29.1	105	0.82	86
5/25/54	23.1	184		
5/31/54	23.8	157		

Site 112, Grand Mesa, Colo.

Date	MC, %	CI	RI	RCI
6/19/53	23.7	241		
6/30/53	17.8	284		
8/4/53	29.4	185		
9/2/53	19.2	300		
4/13/54	34.8	92	0.58	53
4/15/54	31.6	92	0.64	59

Table A3 (Continued)

Site 112, Grand Mesa, Colo. (Cont'd)

Date	MC, %	CI	RI	RCI
4/19/54	33.8	125	0.73	91
4/22/54	29.8	106	0.78	83
4/26/54	33.4	99	0.62	61
5/10/54	30.7	128	0.83	106
5/25/54	26.3	139	0.92	128

Site 114, Lands End, Colo.

Date	MC, %	CI	RI	RCI
6/18/53	24.7	142		
6/19/53	25.5	156		
6/29/53	16.6	207		
9/14/53	17.4	300		
10/26/53	33.6	103	0.74	76
10/27/53	32.8	125	0.76	95
10/29/53	35.0	148	0.80	118
11/2/53	21.4	253		
11/5/53	15.2	246		
11/16/53	22.1	180		
4/12/54	34.6	124	0.49	61
4/16/54	36.0	139	0.69	96
4/19/54	29.8	200		
4/23/54	32.2	131	0.78	102
4/26/54	29.4	145	0.67	97
5/6/54	32.6	110	0.58	64
5/24/54	24.6	207		
5/31/54	23.0	223		

Site 115, Lands End, Colo.

Date	MC, %	CI	RI	RCI
6/29/53	15.8	120		
6/29/53	12.4	235		
4/9/54	23.8	92	0.50	46
4/12/54	24.8	79	0.49	39
4/14/54	21.6	108	0.54	58
4/16/54	24.6	97	0.59	57
4/19/54	21.2	123	0.56	69
4/23/54	21.6	106	0.60	64
4/26/54	19.8	128	0.67	86
5/3/54	24.3	76	0.57	43
5/10/54	23.8	111	0.72	80
5/24/54	19.0	206		
5/31/54	15.3	280		

Site 116, Lands End, Colo.

Date	MC, %	CI	RI	RCI
6/18/53	18.5	300		
6/29/53	17.2	300		
7/13/53	15.8	300		
7/20/53	15.4	242		
3/19/54	25.2	245		
3/22/54	28.2	250		
3/23/54	30.1	219		
4/5/54	26.4	258		
4/9/54	22.3	226		
4/12/54	22.8	246		
4/19/54*	35.4	174		
4/21/54*	32.6	201		
4/23/54*	37.3	112		
4/23/54*	31.2	209		
4/26/54	27.0	199		
4/30/54	27.4	207		

Site 117, Delta, Colo.

Date	MC, %	CI	RI	RCI
7/24/53*	18.7	122	1.62	198
7/27/53*	18.6	173	1.21	209
8/3/53*	19.4	178		
8/5/53*	18.4	213		
8/7/53*	16.5	256		
10/7/53*	13.1	238	1.23	293
10/9/53*	15.2	195	1.22	238
10/12/53*	20.2	204		
10/14/53*	18.0	203		
10/21/53*	19.4	196		
10/22/53*	24.3	153		

Site 119, Delta, Colo.

Date	MC, %	CI	RI	RCI
7/24/53*	10.2	129	2.10	271
7/27/53*	11.4	210		
8/3/53*	9.4	270		
8/3/53*	16.0	180		
8/5/53*	12.9	184		
8/5/53*	10.2	292		
8/7/53*	9.4	285		
8/7/53*	13.8	202		
10/7/53*	7.3	245		
10/9/53*	9.5	267		
10/13/53*	6.0	271		

Site 120, Vicksburg, Miss.

Date	MC, %	CI	RI	RCI
2/24/55	25.2	210		
3/1/55	23.9	235		
3/8/55	23.1	253	0.80	202
3/15/55	22.0	289		
3/22/55	24.9	177	0.56	99
3/22/55	24.0	220	0.65	143
3/29/55	22.5	292		
4/11/55	26.1	175	0.38	66
4/13/55	26.5	171	0.40	68
4/13/55	25.6	148	0.44	65
4/13/55	25.5	178	0.56	100
4/13/55	25.1	162	0.60	97
4/13/55	24.6	179	0.63	113

Site 123, Alexandria, La.

Date	MC, %	CI	RI	RCI
2/4/54	21.3	115	0.76	87
2/11/54	22.1	137		
2/18/54	21.4	167		
2/26/54	22.0	147		
3/4/54	22.0	147		
3/11/54	22.2	138		
3/18/54	22.0	153		
3/24/54	21.8	139		
4/1/54	23.3	148		
4/2/54	23.0	136	0.54	73
4/8/54	21.3	122		
4/16/54	26.0	94		
4/23/54	21.5	114		
4/29/54	23.4	112		
5/6/54	23.2	82	0.67	55
5/13/54	24.8	100		
5/20/54	21.1	132		
5/27/54	22.8	118		
6/4/54	19.3	217		
6/8/54	18.7	232		
6/18/54	16.4	262		
6/24/54	13.7	300		

Site 124, Alexandria, La.

Date	MC, %	CI	RI	RCI
2/3/54	28.4	119	0.22	26
2/11/54	27.0	200		
2/18/54	25.8	240		
2/26/54	24.9	300		
3/4/54	24.3	293		
3/11/54	26.3	286		
3/18/54	21.1	300		
3/24/54	23.9	300		
4/2/54	26.3	180		
4/8/54	25.6	242		
4/16/54	29.3	168		
4/13/54	24.2	227		
4/29/54	26.3	132		
5/6/54	27.3	138	0.28	39
5/13/54	32.2	149		
5/20/54	24.8	252		
5/27/54	25.7	96		
6/4/54	22.0	300		
6/8/54	21.8	300		

Site 125, Robbs, Ill.

Date	MC, %	CI	RI	RCI
4/22/55	30.1	64	0.70	45
4/26/55	30.6	81	0.80	65
4/29/55	27.9	120	0.57	68
5/3/55	26.3	177	0.47	83
5/9/55	22.3	191		
5/18/55	25.6	147	0.39	57
5/20/55	23.5	180		
2/20/56	32.3	64	0.50	32
2/27/56	31.0	68	0.32	22
3/8/56	30.7	99	0.39	39
3/14/56	32.7	76	0.36	27
3/16/56	31.4	104	0.38	40
3/19/56	30.6	84	0.44	37
3/23/56	29.9	93	0.65	60
3/30/56	27.2	120	0.54	65
4/4/56	30.7	89	0.35	31
4/16/56	33.4	66	0.36	24
5/11/56	26.4	147	0.62	91
5/16/56	26.7	132	0.85	112
5/24/56	23.6	195	0.88	172
6/1/56	26.7	125	0.38	48

Site 126, Oxford, Miss.

Date	MC, %	CI	RI	RCI
5/5/54	28.7	113	0.86	97
5/13/54	31.2	107		
3/16/55	35.0	117		
3/21/55	30.2	95		
3/23/55	30.0	121		
3/25/55	26.8	96		
5/19/55	25.2	300		
6/29/55	22.2	300		

Site 127, Oxford, Miss.

Date	MC, %	CI	RI	RCI
5/5/54	22.8	174		
5/13/54	24.1	149		
5/21/54	20.2	248		
3/16/55	24.2	178		
3/21/55	25.6	149		
3/23/55	20.0	178		
3/25/55	21.2	162		
5/19/55	23.0	300		
6/29/55	21.4	205		

Site 128, Oxford, Miss.

Date	MC, %	CI	RI	RCI
5/13/54	27.8	136		
5/21/54	25.6	249		
3/16/55	25.8	163		
3/21/55	27.6	118		
3/23/55	32.0	127		
3/25/55	28.6	141		
5/19/55	13.6	300		
6/29/55	17.7	266		

Site 129, Redwood, Miss.

Date	MC, %	CI	RI	RCI
12/27/56	21.6	300+		
1/7/57	26.4	265		
1/18/57	23.9	296		
1/25/57	28.1	207		
2/4/57	26.5	189		
2/25/57	27.2	255	0.59	150
2/28/57	25.8	253		
3/19/57	25.3	266		
3/27/57	24.7	277		
4/4/57	23.9	265	0.63	167
4/12/57	24.3	287		
4/16/57	24.0	300+		
4/26/57	22.6	300+		
5/23/57	16.4	300+		
6/4/57	23.5	289		
7/9/57	22.8	300+		

(Continued)

* Infiltrometer test (artificial rainfall)

Table A3 (Concluded)

Date	MC, %	CI	RI	RCI
Site 130, Redwood, Miss.				
1/[illegible]/57	21.7	235		
1/9/57	23.3	195		
1/18/57	21.7	300+		
1/25/57	35.5	174		
1/31/57	26.4	231		
2/15/57	22.2	280		
2/25/57	25.3	209	0.52	109
3/1/57	25.5	195		
3/19/57	25.3	231		
3/27/57	23.9	257	0.47	121
4/4/57	26.7	185	0.45	83
4/9/57	24.2	237	0.66	156
4/16/57	23.4	270		
4/23/57	22.1	273		
5/10/57	19.8	280		
5/23/57	17.5	287		
5/29/57	20.4	288		
6/4/57	23.9	241	0.57	137
7/12/57	18.5	284		
Site 131, Valley Park, Miss.				
12/21/56	21.1	300+		
1/9/57	19.9	264		
1/18/57	20.[illegible]	300+		
1/25/57	22.9	209		
1/31/57	23.6	209	0.82	171
2/25/57	28.6	99	0.49	48
3/1/57	27.1	117		
3/19/57	26.5	139		
3/27/57	27.6	126	0.73	92
4/2/57	26.7	114	0.58	66
4/9/57	25.2	146	0.71	104
4/16/57	24.7	170	0.82	139
4/23/57	26.0	142	0.77	109
5/8/57	24.2	156		
5/24/57	26.2	158	0.62	98
5/29/57	25.5	158	0.73	115
6/14/57	24.8	168	0.71	119
7/9/57	23.3	217	0.81	176
7/19/57	18.2	234		
7/26/57	23.2	234	0.79	185
Site 132, Valley Park, Miss.				
12/27/56	44.4	98		
1/8/57	44.8	119	1.11	132
1/18/57	45.4	120	1.07	138
1/25/57	47.4	98		
2/4/57	44.9	107	0.86	92
2/15/57	45.5	123	0.98	120
2/27/57	47.5	86	1.00	86
3/8/57	46.5	115		
4/12/57	47.6	87	1.02	89
4/26/57	45.5	92	0.98	90
5/23/57	35.8	185	1.05	194
6/19/57	41.9	102		
7/12/57	41.6	140	1.01	141
7/19/57	36.9	169		
Site 133, Onward, Miss.				
12/26/56	27.2	160		
1/8/57	21.5	228		
1/18/57	22.7	213		
1/25/57	23.4	221		
1/31/57	27.5	141	0.72	101
2/15/57	28.6	96	0.92	88
2/26/57	27.8	94	0.73	69
3/6/57	27.6	113		
3/27/57	29.2	91	0.72	65
Site 133, Onward, Miss. (Cont'd)				
4/2/57	29.2	75	0.71	53
4/9/57	29.0	112	0.81	91
4/23/57	32.4	87	0.89	77
5/8/57	27.9	125		
5/24/57	26.2	138	0.70	97
5/29/57	26.7	148	0.87	129
6/14/57	27.0	157	0.85	133
7/9/57	25.0	204	0.74	150
7/18/57	19.4	300+		
7/26/57	23.0	244		
Site 134, Onward, Miss.				
12/21/56	51.9	87		
1/8/57	41.2	92	1.05	97
1/18/57	43.8	75	1.33	100
1/25/57	59.3	34		
1/31/57	47.5	94	1.00	94
2/14/57	48.1	85	1.19	101
2/27/57	47.5	83	1.14	95
3/13/57	45.8	80		
4/10/57	47.5	82	0.91	75
4/18/57	41.5	80	0.99	79
4/25/57	41.0	89	0.98	87
5/16/57	40.8	104	1.07	111
7/12/57	35.3	207	0.70	145
7/16/57	28.7	234	1.13	264
8/1/57	29.6	287		
Site 135, Eagle Lake, Miss.				
12/28/56	37.8	163		
1/7/57	36.4	105	1.74	183
1/18/57	38.5	127	0.85	108
1/25/57	39.4	106		
1/31/57	41.1	96	0.93	89
2/14/57	38.8	148	1.00	148
2/27/57	39.5	107	0.94	101
3/5/57	37.1	123		
4/10/57	38.8	120	0.91	109
4/18/57	37.0	109	1.05	114
4/25/57	35.9	110	0.97	107
5/22/57	31.8	178	0.80	142
6/19/57	29.8	231		
7/10/57	31.2	178		
7/16/57	27.4	243		
Site 136, Eagle Lake, Miss.				
12/28/56	27.9	171		
1/7/57	29.5	124	0.91	113
1/18/57	27.9	131		
1/25/57	29.8	126		
1/31/57	31.9	139	0.75	104
2/14/57	29.7	143	0.83	119
2/26/57	30.7	118	0.86	102
3/4/57	29.3	138		
3/19/57	30.3	125		
4/2/57	30.7	120	0.78	94
4/10/57	29.5	128	0.76	97
4/18/57	27.7	151	0.87	131
4/25/57	27.1	157	0.78	123
5/9/57	26.6	178	0.79	141
5/22/57	25.6	185	0.83	153
6/19/57	23.5	212	0.95	201
7/10/57	25.7	172	0.82	141
7/18/57	21.0	252		
8/1/57	17.6	298		
Site 150, Miles City, Mont.				
4/19/54	18.4	236		
Site 150, Miles City, Mont. (Cont'd)				
4/30/54	16.3	252		
5/14/54	15.3	279		
5/24/54	14.8	300		
6/11/54	18.4	300		
6/20/54	27.9	151		
7/1/54	19.7	160		
7/7/54	25.4	226		
7/9/54	19.5	193		
7/14/54	17.8	221		
7/16/54	17.6	195		
7/21/54	18.3	229		
7/23/54	17.1	190		
Site 151, Miles City, Mont.				
4/8/54	25.1	194		
4/19/54	25.5	182		
4/30/54	23.4	232		
5/14/54	20.2	300		
6/22/54	27.1	177		
6/28/54	27.4	129		
6/30/54	24.5	194		
7/9/54	20.4	300		
Site 152, Miles City, Mont.				
4/19/54	17.5	241		
4/30/54	15.1	251		
5/14/54	11.5	300		
5/28/54	25.4	126	0.70	86
6/30/54	24.0	140	0.60	84
7/7/54	18.9	219		
7/9/54	16.4	280		
7/14/54	14.6	289		
7/16/54	13.1	300		
7/21/54	11.5	293		
Site 153, Rockford, Wash.				
3/12/54	33.1	44		
4/2/54	29.2	60	0.24	14
4/16/54	28.2	63	0.38	24
4/30/54	27.1	83	0.48	40
5/14/54	24.1	100	0.60	60
5/20/54	22.1	118	0.90	106
6/2/54	28.0	86	0.41	35
Site 155, Rockford, Wash.				
3/22/54	36.3	149	0.22	33
4/13/54	31.5	195	0.26	51
4/23/54	33.5	231	0.39	90
4/28/54	33.7	214	0.32	68
5/5/54	32.0	238	0.76	181
5/14/54	28.1	253	0.56	142
5/20/54	28.3	257	1.05	270
6/2/54	28.1	270	0.97	262
6/9/54	24.9	284		
Site 156, Rockford, Wash.				
3/22/54	36.9	80	0.49	39
4/1/54	35.1	104	0.73	76
4/14/54	35.4	95	0.63	60
4/27/54	32.7	126	0.63	79
5/14/54	44.7	72	0.25	18
5/14/54	29.0	171	0.93	159
5/20/54	24.3	220		
6/2/54	24.8	170		
6/9/54	24.9	157	0.90	141

APPENDIX B: SOIL STRENGTH MEASURES

1. Included in this appendix are brief descriptions of the equipment used and procedures* followed in measuring cone index (CI), remolding index (RI), and rating cone index (RCI) for this study.

Cone Index

Equipment

2. CI was measured with a 0.5-sq-in. cone penetrometer, the principal instrument used to evaluate soil trafficability at the WES. The instrument consists of a 30-deg right circular cone having a basal area of 0.5 sq in. mounted on one end of a 5/8-in.-diam staff; mounted on the opposite end are a proving ring with micrometer dial gage and a handle. When the cone is forced into the ground, the proving ring is deformed in proportion to the force applied. Twice the amount of force in pounds required to move the cone slowly through a given plane is indicated on the dial. The dimensions of a dial reading (pounds per square inch) are generally disregarded, and the reading is considered to be only an index of shearing resistance. The range of readings for a 0.5-sq-in. cone penetrometer is from 0 to 300. A disassembled cone penetrometer is shown in fig. B1.

Use of equipment

3. In use, the palm of one hand was placed directly over the handle of the penetrometer and the other palm was placed over the back of the first hand as shown in fig. B2a. This type of grip permitted a uniform and well-controlled force on the handle. The cone was then slowly pushed into the soil until its base was flush with the soil surface. At that point the movement of the cone was momentarily halted and the force released. The force on the handle was then reapplied slowly and uniformly until the cone began to move again; a dial reading made at that instant was the surface cone index. CI readings for any given depth were made similarly, i.e., by pushing the cone to the desired depth, releasing the force on the handle

* At the time of this study, the procedures described herein were standard; they were subsequently modified.

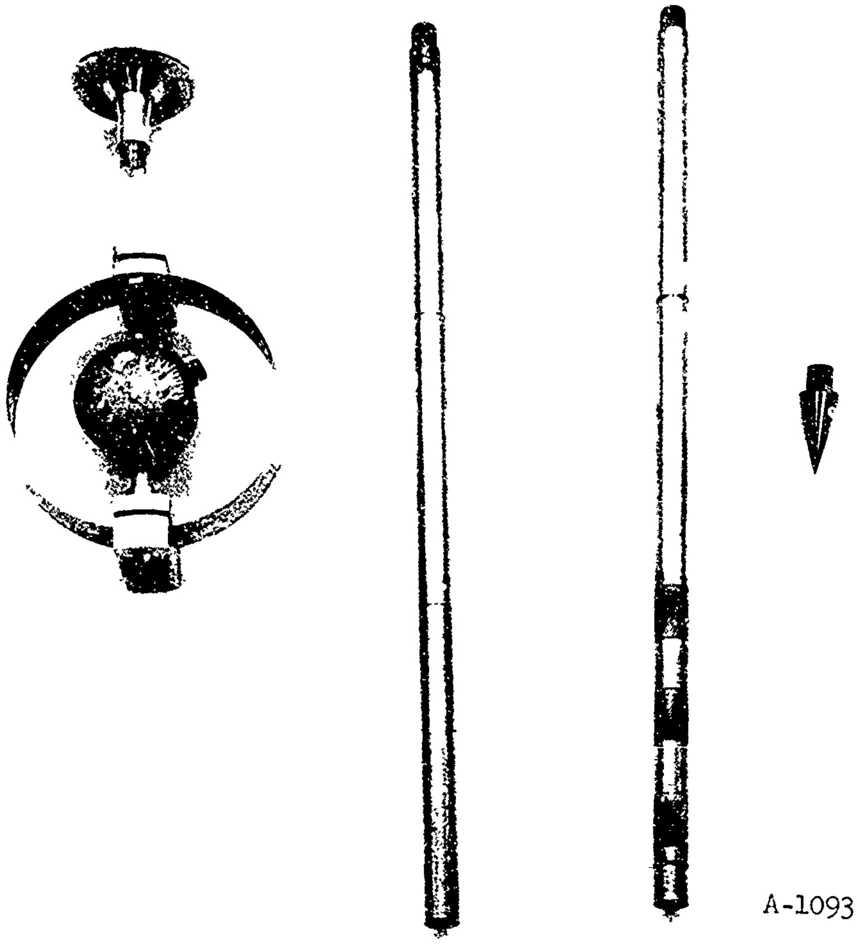


Fig. B1. Cone penetrometer (disassembled)

a. Cone penetrometer b. Trafficability sampler c. Remolding equipment

Fig. B2. Equipment used in measuring soil strength

momentarily, reapplying the force, and reading the dial just as the cone began to penetrate again.

4. In obtaining CI data for a site during a given visit several penetrations were made with readings being taken at the surface and at 3-in. intervals from the surface to the 18-in. depth or until the soil became too firm to penetrate. For a given penetration, the first depth at which a reading greater than 300 was encountered was assigned a value of 300; if further penetration could not be made, lower depths were generally assigned values of 300+.

Computations

5. To compute the 6- to 12-in. CI for a visit at a site the CI readings for the 6-, 9-, and 12-in. depths were first averaged by depth. The average 6-, 9-, and 12-in. depth CI's were then averaged to obtain the average CI of the 6- to 12-in. layer for the site.

6. Procedures for treating 300 and 300+ readings in the averaging process were as follows. If two-thirds or more of the readings for a given depth were 300 or 300+, the depth was assigned a value of 300+. If all three depths were assigned 300+ values, the 6- to 12-in. layer for that site and visit was also assigned a value of 300+. Otherwise, 300+ readings were assumed to be 300 for averaging purposes. It can readily be noted that a site average CI based on readings of which one or more were 300+ was, in practically all cases, lower than the actual average CI that existed at the time of measurement.

Remolding Index

Equipment

7. Three pieces of equipment were used in making a RI test: (a) a trafficability sampler, (b) a remolding set, and (c) a cone penetrometer.

8. The trafficability sampler is a piston-type soil sampler designed for obtaining relatively undisturbed samples from comparatively soft soils. Samples approximately 2 in. in diameter and 7 in. in length were used for making remolding tests (samples cut to specified lengths were also used in making density and gravimetric moisture determinations). The primary

purpose of the piston is to maintain a partial vacuum above the sample; this helps prevent compression of the sample as the sampler cylinder is forced into the soil and helps prevent the loss of the sample as the cylinder is removed from the soil. Its secondary purpose is to force the sample from the sampler cylinder. A trafficability sampler, disassembled, is shown in fig. B3.

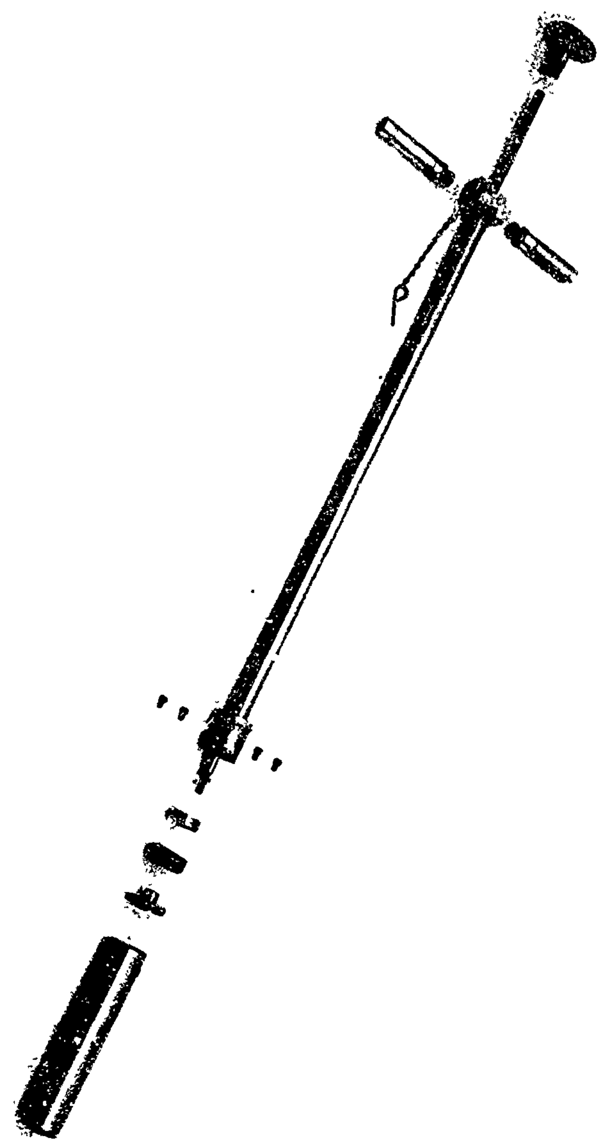


Fig. B3. Trafficability sampler (disassembled)

9. A remolding set consists of a cylinder mounted vertically on a base and a 2.5-lb drop hammer that is free to travel 12 in. on a shaft fitted with a circular foot on one end and a handle on the other end. The cylinder diameter is the same as that of the trafficability sampler cylinder. A remolding set is shown in fig. B4.

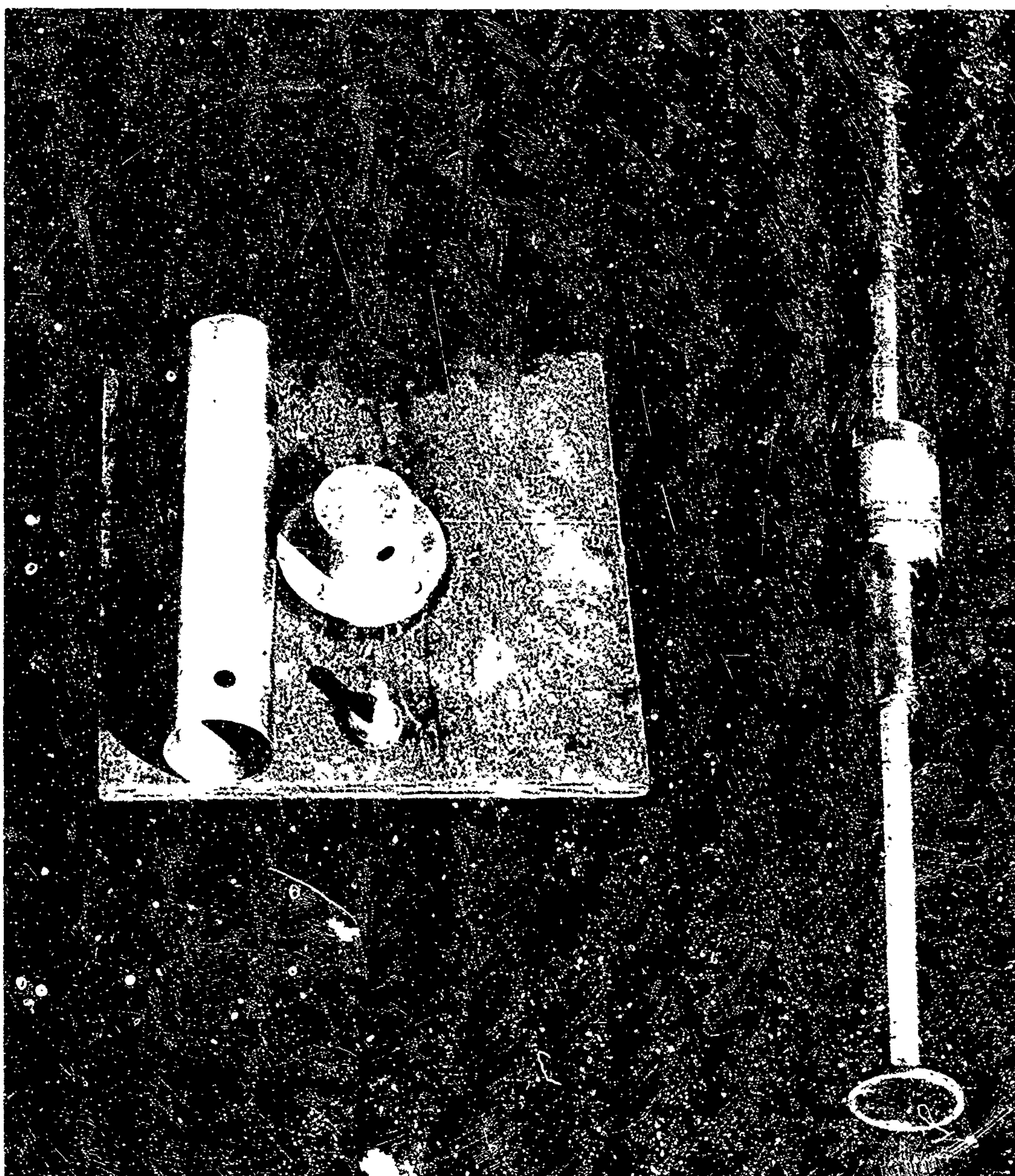


Fig. B4. Remolding set

10. Either a 0.2-sq-in. or a 0.5-sq-in. basal area cone penetrometer is used in making a remolding test. The 0.2-sq-in. penetrometer is similar in construction to the 0.5-sq-in. penetrometer except that the shaft and cone are smaller. Five times the amount of force in pounds required to move the cone slowly through a given plane is indicated on the dial; therefore, the dimensions of a dial reading are the same for both penetrometers, i.e. pounds per square inch (see paragraph 2). The range of readings for a 0.2-sq-in. cone penetrometer is from 0 to 750.

Use of equipment

11. In making a remolding test, a sample was obtained from the 6- to 12-in. soil layer and ejected directly into the remolding cylinder. The sample was then pushed to the base of the cylinder with the drop-hammer foot. CI readings were taken at 1-in. intervals from the sample surface to the 4-in. depth. The sample was then remolded and CI readings were made at the same depths as prior to remolding.

12. For fine-grained soils the 0.5-sq-in. cone penetrometer was used, and remolding of the sample was accomplished by applying 100 blows with the drop hammer (fig. B2c). For sands with fines, poorly drained, the 0.2-sq-in. cone penetrometer was used, and remolding of the sample was accomplished by dropping it (along with the cylinder and base) 25 times from a height of 6 in. onto a firm surface.

13. In making a penetration, either before or after remolding, the first depth that was stronger than the capacity of the penetrometer and all succeeding depths were assigned values of 300+ (for the 0.5-sq-in. penetrometer) or 750+ (for the 0.2-sq-in. penetrometer). A test was considered valid unless readings both before and after remolding at the 1-in. depth were 300+ or 750+.

Computations

14. The 6- to 12-in. RI for a visit at a site was computed as follows. For each sample the sum of the CI readings after remolding was divided by the sum of the CI readings before remolding, the quotient being the RI of the sample. The RI's of all tests were then averaged to obtain the average RI for a visit.

15. In summing CI readings before and after remolding, only

corresponding depth values were included. A 300+ (or 750+) value was used providing that its corresponding before or after depth value was less than 300 (or 750); a 300+ (or 750+) value was not used if its corresponding before or after depth value was also 300+ (or 750+). In summing, 300+ (or 750+) readings were treated as being 300 (or 750). As opposed to CI, there is no indication that consistent errors in RI resulted from the prescribed treatment of 300+ (or 750+) values in the averaging process (see paragraph 5).

16. The RI has been referred to in this report as well as others as a measure of soil strength. In actuality, the RI is a ratio of strengths (CI's) and is, therefore, nondimensional.

Rating Cone Index

17. The average RCI for a visit at a site is the product of the average CI and average RI. It is accepted as an index of the shearing resistance of the soil after it has been subjected to 40-50 passes of a vehicle.